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FOR PROMOTING EXPERIMENTS IN
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1926 and 1927

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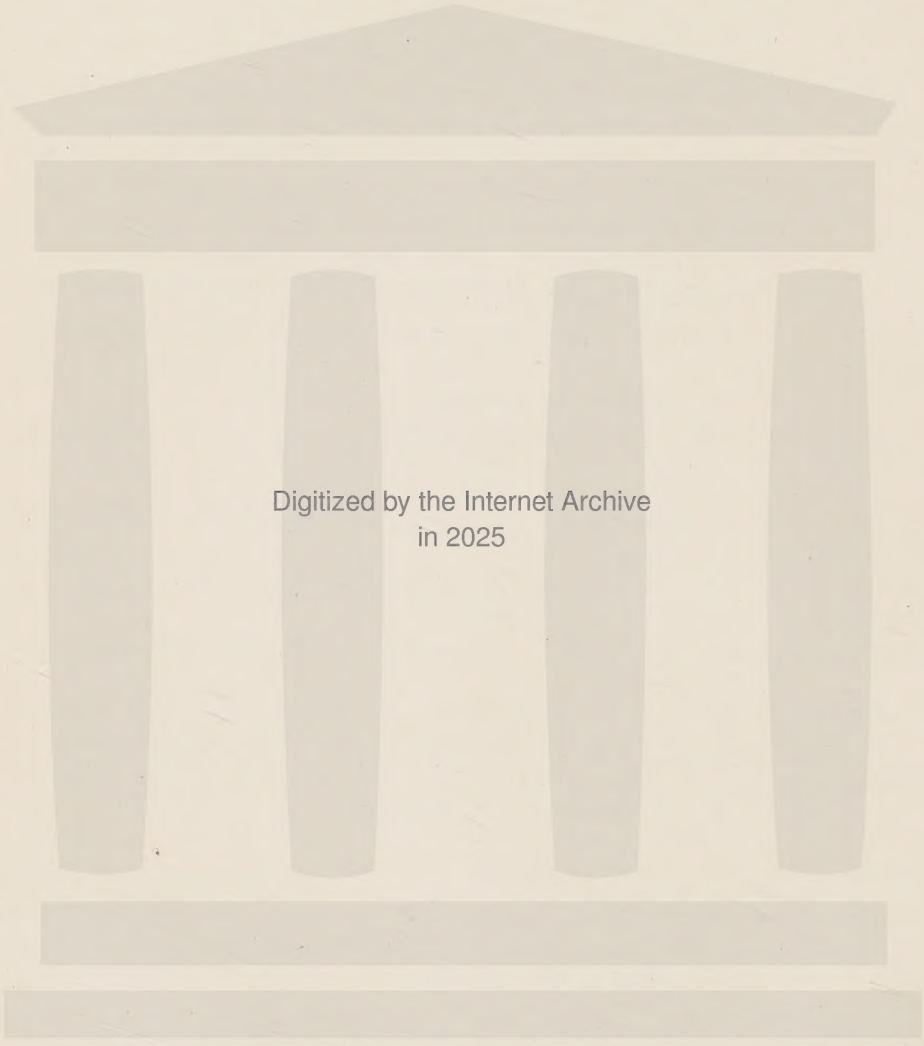

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# THE VEGETATIVE PROPAGATION OF FRUIT-TREE ROOTSTOCKS.

By R. C. KNIGHT, J. AMOS, R. G. HATTON, and A. W. WITT.

## Introduction.

Horticultural research work during recent years has resulted in fuller recognition of the importance of a general principle, the establishment of which must have coincided with the inauguration of horticulture itself. The selection of varieties and their maintenance and multiplication as pure lines has, in a general way, always been the aim of the cultivator, but with the increase in our knowledge of the subject has come an extension of this principle, so that it is applied not only to an ever-increasing range of varieties, but also in greater detail and more intensively to any one variety.

It is even found almost essential for experimental purposes, and undoubtedly desirable for commercial work, to raise pure lines from single parent plants.

Rigorous selection and " roguing " are now routine matters in plantations of small fruits, and as far as scion is concerned the same processes have been applied to top fruits. Modern practice has also seen a considerable development of the principle in relation to rootstocks, to which less attention has been given in the past than to scions, although the relative importance of the two portions of the tree has in some measure been realised.

It is inopportune and unnecessary here to elaborate the reasons for the selection and maintenance of true lines of rootstocks. The question, which has been fully dealt with elsewhere (see for example 1, 2, 3, 4 and 7), has two main aspects, namely the propagation of the stocks and their potentialities and performance.

A considerable amount of information is now available concerning the performance of the rootstocks of most of the tree fruits (4, 7, 10, etc.), as a result of which, emphasis is laid on the desirability of using pure lines of stocks, owing to the differences which exist between varieties.

Genetic differences result in differences of compatibility, precocity, vigour and other factors, all of which have a considerable significance from the point of view of the nurseryman, the grower and the experimenter. In order to take full advantage of these genetic differences and their consequences, it is essential that pure lines of plants be used, and the only practical method at present available for effecting this is multiplication by vegetative propagation.

The stocks for the tree fruits are still raised in large numbers from seed, a method which is relatively simple and which also owes some of its popularity

to tradition and long usage. Whilst there is no doubt that it is an easier and less involved operation to raise stocks from seed rather than by vegetative methods, yet even in course of seedling propagation, some disadvantages, which are due to the varietal differences, appear. For example, only a proportion of the material in the seed-bed is large enough or of suitable growth for budding or grafting. Other aspects of the question of suitability of stocks from the propagator's view point will be considered later.

As a result of recent work on the performance of tree fruits in relation to rootstock, considerable emphasis has been laid upon the importance of vegetative propagation, which is considered to be the only efficient method of maintaining the genetic purity in rootstocks which is necessary in order to afford a means of controlling the scion through the stock. At the same time it has always been realised that the vegetative method is not one to be advocated and then lightly dismissed. It is not sufficient merely to record the potentialities of a stock and to recommend its multiplication and use, since the capacity for vegetative reproduction is a factor which varies with different varieties in the same way as do other characteristics.

Consequently, an intensive and extensive study of propagation has necessarily accompanied the study of rootstock performance already referred to.

Empirical trials have been conducted over a period of twelve years, applying a wide range of methods to a great variety of subjects, and at the same time some investigation has been made into the general principles underlying the regeneration processes involved in vegetative propagation.

As a result of this series of trials it has been found possible to propagate vegetatively by some means or other, every variety of fruit plant and rootstock which has been exhaustively tested. Some distinction must, however, be drawn between mere successful propagation, and propagation on such a scale, and by such methods as are likely to be of economic value. In the majority of cases methods have been found which are definitely practicable under commercial conditions, whilst in a few instances the operations have not yet perhaps been reduced to the limits of profitable practice. Even in these latter cases, however, it has been found of the utmost value to be able to establish pure lines (even if by relatively troublesome means) for experimental purposes, and it remains to be seen whether modification of the methods will result in the possibility of wider application.

It may be pointed out at the outset that in the choice of a variety, whether it be a self rooted variety, a scion, or a stock, one of the factors constituting desirability must necessarily be ease of propagation. Whilst chief emphasis is naturally laid upon performance, it is equally natural to set store by a variety which is readily multiplied. It must be recorded, however, in this connection that in the past too much emphasis has unquestionably been laid upon this

latter fact, with the result that performance has not received its due share of attention.

Stock-scion combinations have often been used, largely because the stock is easily raised or the union is readily effected, and the mutual influence of the two units in later life, together with its effect on performance, has been somewhat obscured.

It cannot be too strongly emphasised that the results obtained in the trials to be considered here have shown that *it is much easier to improve the propagation of a variety of good performance, than to improve the performance of a less desirable variety, which happens to be easily propagated.* Cultural treatments through the profitable life of a plant may contribute largely to securing proper performance, but it is manifestly better practice to solve, once and for all at the outset, one important aspect of this problem, by taking steps to obtain success in the propagation of a variety known to possess good qualities, instead of selecting for simplicity of propagation and relying on later treatment to obtain the desired performance.

In this connection also it must be realised that not only is it necessary to use different propagation methods for different species and genera, but even varieties closely similar to each other frequently respond quite differently to the same treatment. Consequently, the propagation problem resolves itself at first into a series of empirical trials with every variety required. Elucidation of the principles involved is of considerable value in a general way, but application of these principles to each individual variety is handicapped by this wide variation of inherent potentialities.

A considerable amount of information upon the suitability of different methods of propagation for different stocks has already been published (5, 6) but the additional experience since gained makes it desirable to bring up to date the publication of our knowledge.

## Methods of Vegetative Propagation.

In multiplying the wide range of plants involved in this work a variety of methods has been employed. Stools, layers, hardwood and softwood stem cuttings and root cuttings have all been used to multiply rootstocks or varieties on their own roots. Suckers are, of course, also used in commercial practice.

These methods will be described in detail later, but it is significant to observe here that in the case of a variety (Brompton) which has been propagated by every one of them, the resulting plant has the same characteristics, by whatever means it is obtained. There is apparently no difference in root character or general vigour, which is thus dependent upon inherent qualities of the plant. This is to be expected, but it is important in view of the necessity of using different procedure for different varieties.

Of these methods of propagation it appears *a priori* that the most satisfactory is that by hardwood stem cuttings. It has the advantage that the material required is easily obtained, which is not always the case if root cuttings are used. The area occupied by stem cuttings is, even in extreme cases, not greater than that required by layers and stools. Further, after planting, hardwood stem cuttings require less attention than do either layers, stools or softwood cuttings.

The attraction of the hardwood stem cutting method, however, is greatly discounted by the fact that only a small proportion of the varieties used for rootstocks will show satisfactory rooting when subjected to it under ordinary conditions, and consequently advantage must be taken of other methods in spite of the greater trouble and expense involved in applying them.

### 1.—Stools.

The principle involved in propagation from stools is the annual production, as the result of excessive winter pruning, of numbers of new shoots, at or about ground level, from the stem-crown of the parent plant, which remains *in situ* permanently. These new shoots are induced, whilst still attached to the parent stool, to produce roots from their bases over a length of stem from 2 to 4 inches.

This is effected by surrounding them with soil under suitable conditions the nature of which depends on the variety involved, and which are detailed below.

#### Method.

In order to establish a stool bed, young individuals (even one year old plants may be used) are planted 2 feet apart in rows, each row being $3\frac{1}{2}$ feet from its neighbour. Each plant is lightly tipped before growth commences and is allowed to grow thus for one season. In the following winter each plant is cut back to within 2 inches of ground level, and is thus stimulated to produce, during the following season, new shoots from buds at the base.

Up to this stage the procedure is identical for all varieties, but thereafter the treatment must be varied to suit the characteristics of different subjects. There are two factors which must be considered in determining procedure during the growing season, namely the number of new shoots produced by the variety from the stool, and the facility with which these shoots produce roots. Unfortunately, the optimum of external conditions for shoot production is not the same as that for rooting. The greatest number of new shoots is obtained when the crown of the stool is exposed to light and air, but on the other hand, shoots emerging under these circumstances do not develop roots as well as shoots which have arisen from a stool lightly covered with soil. These latter shoots, as a result of developing at first in darkness, are etiolated at the base, and

Mounded Stool of Apple, showing Crop of Current Year's Shoots in the Growing Season.

FIG. 2.

Stool of Apple, showing Roots arising from Current Year's Growth, as well as Older Roots of Parent Plant.

FIG. 3.
Method of Layering a Shoot.

FIG. 4.
New Growths arising from a Layered Shoot of Plum, the Parent Stem having been covered with Soil previous to Bud Break.

rooting from this etiolated portion is much freer than from a stem which has developed normally in light. This applies not only to shoots from stools and layers, but also to stems used as cuttings, from which better rooting is obtained when their bases have been etiolated during growth.

In the case of apples, rooting from stool shoots is usually free, and consequently the stools are allowed to remain uncovered at the beginning of the season when new shoots are developing, whilst if plums are grown as stools, the plants must be lightly covered with soil before bud-break. When the new shoots are 4 to 6 inches high, soil is mounded around their bases to a depth of 2 inches. Later when the shoots have reached a height of 8 inches, more soil is added to the mound and the process is repeated until each stool is covered with 5 to 6 inches of soil. It is better to carry out the mounding operations when the soil is slightly moist, and the tender tops of the young shoots must never be covered, or losses from decay will result. During the mounding processes, the new shoots should be spaced out evenly and the mass of soil on the middle of the stool bends them slightly outwards away from the centre. This latter treatment tends to produce better rooting, especially with vigorous shoots from young stools.

When the requisite amount of soil has been added to the mound, the plants are allowed to remain undisturbed during the rest of the growing season, and adventitious roots are produced on the stems between the parent stool and the top of the mound.

Fig. 1 shows a stool towards the end of the growing season, after the mounding process has been completed, and Fig. 2 shows a similar stool with the soil drawn away. In this case the young shoots are seen to have produced adventitious roots as described above. The coarser roots shown at the base of the stool in this figure are those growing from the original plant, and not newly formed roots from the young shoots.

In November, the soil is drawn away, and the rooted shoots are removed from the stool and planted out, as required, for working. Whether obtained from stools or layers (described below), stocks for apples and pears are planted one foot apart in rows which are three feet apart, whilst stocks for plums and cherries are planted one foot apart in rows which are four feet apart. About six inches of the base of the stem are placed below ground level and the soil is firmly trodden. Such stocks are fit to bud in the July following their removal from the parent plant, or they may be grafted after one season's growth subsequent to planting. Thus a good maiden is secured within two years of removal from the stool or layer.

In the experimental nursery at East Malling, in order to be sure of dealing with rootstocks of a uniform age, the entire crop of shoots (rooted and unrooted) is removed annually. In common commercial practice, only those are removed

which are rooted, and thus many vigorous unrooted shoots remain on the stool for a second year.

Whilst there is no doubt that the removal of the whole crop annually may tend to weaken the stools, nevertheless, when more than one or two *strong* unrooted shoots are allowed to remain on the stools for a second year, the new crop in that second year is very much reduced, and the two-year-old shoots become coarse, and tend to be uneven. Further, this method also undoubtedy results in the production of a high percentage of stocks requiring bedding for one or more years before working. Consequently, with the exceptions referred to on p. 17, it appears desirable to adopt the first method, and, if, as the result of annual denudation, the stools become weakened, the whole crop may be allowed to remain on the stool for two years instead of one. Thus the plant is rejuvenated and will produce a full crop in the season following the removal of these two-year shoots.

The stooling method is adopted, when applicable, in preference to layering, as the former involves less trouble and expense, as will appear subsequently.

### Varieties.

It has been found possible to multiply any variety of apple stock by this method, except Northern Spy and some types of selected seedlings (e.g., A, C, and H) which must be layered and covered with soil before bud-break. (See "Layers" below.)

The less vigorous varieties of Quince and Plums, such as Brussels, Damas C and Myrobolan B are also easily propagated from stools, though in the case of the plums, the stools must be covered with soil before the shoots emerge, as described below, for the layering method, or rooting will not be satisfactory.

A detailed list of the varieties for which the stool method is satisfactory will be found in the appendix.

### Number of Plants Obtained.

Naturally the number of shoots obtained from a stool increases, within limits, with the age of the stool. In the first season after stooling only from four to eight shoots may be expected, and the number increases every year until each stool gives from ten to fifteen first grade* shoots.

Some varieties, such as the vigorous apple stock No. XIII, will produce as many as twenty-five shoots per stool, whereas only eight or ten may be obtained from the Jaune de Metz stock (No. IX). Of these shoots it is usual to find more than 80 per cent. well rooted, although here again the numbers differ with the variety, apple stock No. XV having been known to produce roots on only 65 per

* "First-grade" shoots are those which at the end of the season have a diameter of over $\frac{1}{4}$ in.

cent. of its stool shoots, and at the other extreme Nos. XIII and VI have rooted to the extent of 95 per cent. Of these rooted shoots, some 50 per cent. to 80 per cent. would be classed as first grade, and would be fit for budding in August after planting out direct from the stools.

Table I. shows the average numbers of plants obtained from 100 feet run of stool-row of a representative range of apples and quinces with four-year-old plants, two feet apart in the row.

Table I.

*Approximate Numbers of Shoots obtained from 100 ft. Run of Stools.*

| Variety. | No. of Shoots. | No. Rooted. | No. First Grade. |
|---|---|---|---|
| *Apple Stocks :* | | | |
| No. XIII. .. .. .. | 1200 | 1150 | 900 |
| ,, I. .. .. .. | 800 | 650 | 450 |
| ,, XVI. .. .. .. | 750 | 550 | 350 |
| ,, II. .. .. .. | 700 | 560 | 360 |
| ,, IX. .. .. .. | 450 | 360 | 200 |
| Northern Spy .. .. .. | Practically | no | Rooting |
| Selected Seedlings : | | | |
| A. .. | 2,000 | Nil. | — |
| C. .. | | | |
| H. .. | | | |
| *Quinces :* | | | |
| Angers (A) .. .. | 3,000 | 2,800 | 1,200–1500* |
| Common (B) .. .. | | | |
| C .. .. .. | | | |
| Fontenay (D) .. .. .. | 3,000 | Nil. | — |
| Portugal (E) .. .. .. | 1,000 | Nil. | — |
| F. .. .. .. .. | 2,000 | Nil. | — |
| G. .. .. .. .. | 2,000 | Nil. | — |

* First-grade quince stocks would not be quite as large as first-grade apple stocks, but would be suitable for working.

It will be understood that the less vigorous varieties need somewhat higher cultivation than the more vigorous ones, and in the absence of this, it may happen that the stools become progressively weaker after a time. In such cases it is advisable not to remove all the shoots every year, and in fact it is good practice to leave on the stool each season, some of the *very weak* growths, which are produced in addition to those which are vigorous enough for working in the nursery.

It cannot be too strongly emphasised that conditions of soil and climate have a profound influence upon the success of this and all other methods of propagation here discussed. The figures which are quoted from time to time in this paper were obtained in experiments carried out in a medium loam soil, conductive to strong growth, in an area where the average annual rainfall is approximately 26 inches. There is no doubt that a much lighter soil, coupled

with heavier rainfall, would provide conditions very much more suitable to the purpose of vegetative propagation methods.

## 2.—Layers.

Although the stooling method is of great practical utility for apples and quinces, it unfortunately is not applicable to most plum and cherry stocks and for these a different procedure must be adopted. With a few exceptions the new adventitious shoots produced by these varieties from severely pruned stools do not root readily, even if etiolated, and in order to obtain a reasonable crop it is necessary to take advantage of the buds upon one-year-old shoots which have been previously laid horizontally. The shoots produced from these buds are induced to develop roots by a mounding process similar to that described above, for stools.

Unfortunately, when shoots develop normally from the buds on the laid stems of the plums, root production is very sparing following subsequent mounding and steps must be taken to induce freer rooting. This is effected, as indicated earlier, by excluding light from the buds during the early stages of their development by means of a thin layer of soil. The young shoots thus develop in the dark and push their way through the soil above. Such shoots are etiolated at their bases and develop a satisfactory root-system, but it must be observed that this improved rooting is obtained often at the expense of a reduction in the total crop of shoots, which is the unavoidable result of earthing up prior to the breaking of the buds.

### Method.

Under conditions at East Malling it has been found convenient to space one-year-old rooted plants in rows 4 feet apart, leaving 3 feet between individuals in the row. Planting is carried out so that the main stems lie along the row obliquely at an angle of 30°-40° to the horizontal, and beyond normal cultivation and spraying, the plants are allowed to grow for a season without further attention. During the following winter the main stems and strong laterals are lightly tipped, weak laterals are pruned to two or three buds from the base and the whole plant is laid and pegged down into a shallow drill along the length of the row, so that the stems are about 2 inches below ground level. *Just before the buds break* these stems are covered with not more than 1 inch of fine soil. It is important that this layer of soil should not be too deep, or many of the buds will fail to develop at all. The new shoots have thus to push their way through a layer of soil, and the basal portion is etiolated, remaining whitish in colour and retaining a sappy condition. When these shoots have reached an average height of about 3 inches above the soil, more fine soil is added to the mound,

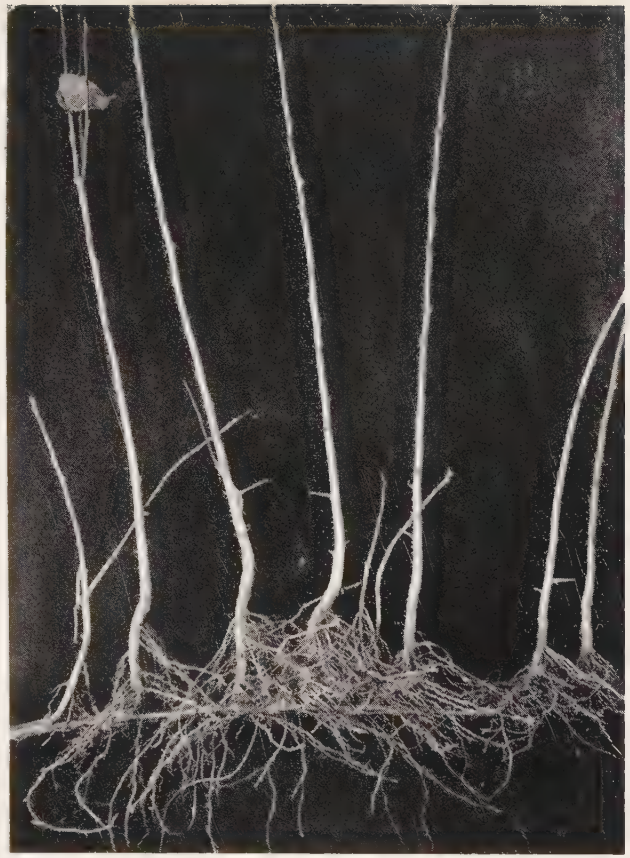

FIG. 5.

Layered Stem of Pershore Plum, showing New Roots arising from Current Season's Growth.

FIG. 6.

Shoot from a Layer of Common Plum, showing New Roots and Point of Attachment to Parent Plant.

Fig. 7.
Plant of Brompton Plum obtained from a Root Cutting.

Fig. 8.
Plant of Brompton Plum obtained from a Hardwood Stem Cutting.

and the process is repeated at intervals until the layered stems are covered to a depth of 5 or 6 inches, after which the plants require no further attention till the dormant season.

Rooted shoots are removed from the parent stems in winter and are planted out in the nursery, and the parent plants are left uncovered until just before bud-break, when they are again subjected to the treatment just described. The process is repeated in following seasons, and successive crops of rooted shoots are thus obtained.

It is found that the most vigorous shoots arising from the layer frequently fail to root during the year of their development, and these are used to supplement the original laid system. They are left attached to the plant and are pegged down into the drill beside the shoot layered in the previous year. Care must be taken to lay these new shoots at the same level as shoots of previous years, so as to avoid differences in the depth of the soil covering when mounding begins. If a shoot is covered too deeply, buds fail to break, whilst if the soil is too shallow, etiolation is not satisfactory.

Care must be taken in removing the rooted shoots from the layered stem, since there is considerable danger of lifting the latter slightly from its bed, and after a few years it may thus be lifted inconveniently above ground level. This tendency is somewhat counteracted by layering always in the shallow drill.

In some cases, such as most of the apples, it is found possible, even in the layering method, to allow the young shoots to reach a length of 5 or 6 inches, before any mounding is attempted, since satisfactory rooting takes place in these varieties, as described in discussing the stooling method, without etiolation. Even here, however, it has been found desirable to encourage rooting of the more vigorous varieties in the early years of the establishment of the parent plant, by mounding before bud-break, dispensing with this part of the procedure as the layers grow older.

Fig. 3 shows the method of layering a stem for the production of new shoots, and Fig. 4 shows the young shoots arising from such a layer, pushing their way through a thin covering of soil which has been placed upon the parent stem before its buds had begun to grow. Fig. 5 shows new shoots arising from a layered stem, and the new roots which they have produced. Fig. 6 shows a single rooted shoot after removal from the parent layer.

It will be observed that throughout this discussion of methods of propagation, considerable emphasis is laid upon the *age* of the parent plants and upon the *vigour* of the new shoots, in relation to the production of roots upon the latter. This is a very important matter, the full significance of which is not yet fully understood, but these two factors are certainly closely inter-related. These methods of propagation involve a system of removal of shoots (which is really a process of very severe pruning), carried out annually upon the parent plants,

and it is well known that such practice results in the production for several years of vigorous and sappy new growth, which in turn is often the least satisfactory material for propagation. The most vigorous shoots generally produce roots with less facility than those of moderate growth, and thus it is unfortunately a fact that these methods of propagation involve a process which tends to make the crops of shoots, for a year or two, less suitable for their purpose. This tendency is certainly counteracted by the fact that, as the plants grow older, the shoots coming from them tend to decrease in vigour, and to increase in number, and so it is frequently found that with varieties in which rooting is difficult in the early years, more and more success is obtained by similar procedure as the plants become older.

It should be stated that there exist in commercial practice some variations in the details of the layering processes, indicating the necessity for adaptation of the method to suit local circumstances.

### Varieties.

It has been found necessary to apply the layering method to most of the plum stocks, a few of the apples, the stronger varieties of quince (and also the weaker Fontenay), the pears and the cherries, although there are indications that the last may be satisfactorily multiplied from stools when these have become established for a few years. It may be recorded as a matter of interest that this method has been applied successfully to some thirty commercial varieties of apples as well as to the stocks, and several plums respond well to the treatment, though in general these gave no promise of being capable of commercial propagation in this way.

Further details of the response of different varieties to layering will be found in the Appendix.

### Number of Plants Obtained.

As in the case of stools, the number of new plants obtained increases with the age of the parent plant. Not only are more new shoots produced in the later years, but also root production is more abundant. This latter feature is of great importance, since it has been found that in both the stooling and layering methods, as already stated, varieties which have completely failed to produce roots on the new stems in the early years, have been successfully propagated when the parent plants have grown older.

As in the stooling method, the number of plants obtained by layering depends very much upon the variety used. Table II. gives some details of the results

which have been obtained. The numbers given are intentionally very conservative, and it is probable that considerably larger numbers could be obtained under good commercial conditions.

## Table II.

*Approximate Numbers of Shoots obtained from* 100 *ft. Run of Layers.*

| Variety. | No. of Shoots. | No. Rooted. | No. First Grade. |
|---|---|---|---|
| *Apples :* The figures are very similar to those given in Table I. for stools, except in the case of :— | | | |
| Northern Spy .. .. .. | 800–1,000 | 600–700 | 500-600 |
| Selected Seedlings : A. .. C. .. H. .. | 2,000 | 800 | 650 |
| *Plums :* | | | |
| Common Mussel .. .. | 550 | 450 | 350 |
| Common Plum .. .. .. | 600 | 550 | 450 |
| Myrobolan B. .. .. .. | 600 | 550 | 450 |
| Black Damas C. .. .. | 700 | 650 | 400 |
| Pershore .. .. .. | 200–400 | 150–200 | 125–200 |
| Brompton .. .. .. | 700 | 500 | 450 |
| St. Julien A. .. .. .. | 500 | 400 | 300 |
| *Pears* (Selected Seedlings): | | | |
| $B\frac{1}{8}$ .. .. .. .. | 700 | 400 | 300 |
| $B\frac{2}{8}$ .. .. .. .. | 600 | 350 | 225 |
| $B\frac{2}{5}$ .. .. .. .. | 600 | 350 | 225 |
| *Cherries :* | | | |
| Mazzard $F\frac{9}{1}$ .. .. .. | 500 | 450 | 350 |
| Mazzard $F\frac{6}{9}$ .. .. .. | 500 | 400 | 300 |
| Mazzard $F\frac{4}{1}$ .. .. .. | 500 | 400 | 300 |
| Mahaleb $F\frac{7}{1}$ .. .. .. | 900 | 50 | 50 |
| Mahaleb $F\frac{7}{3}$ .. .. .. | 900 | 50 | 50 |

It should be emphasised that the figures given in the above Table are necessarily only approximate. The success obtained varies in different season, and some of the variation appears to be due to climatic conditions. Table III. gives a selection of the results obtained with plums over different seasons, showing the differences in the percentage of the new shoots which produced roots.

## Table III.

*Percentage of Layer-Shoots of Plums, which produced roots.*

| Variety. | 1920. | 1921. | 1922. | 1923. | 1924. | 1925. | 1926. | 1927. |
|---|---|---|---|---|---|---|---|---|
| Pershore .. .. .. .. | 70 | 35 | 15 | 40 | 20 | 40 | 70 | 50 |
| Brussels .. .. .. .. | 95 | 95 | 70 | 90 | 90 | 80 | 90 | 95 |
| Brompton .. .. .. .. | 50 | 27 | 20 | 50 | 40 | 70 | 70 | 90 |
| Common Mussel .. .. .. | 60 | 70 | 70 | 75 | 70 | 70 | 75 | 75 |
| Common Plum .. .. .. | 95 | 75 | 95 | 90 | 95 | — | — | — |
| Myrobolan A. .. .. .. | 90 | 50 | 50 | 65 | 60 | — | — | — |
| Myrobolan B. .. .. .. | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 |
| St. Julien A. .. .. .. | — | 75 | 75 | 85 | 85 | 95 | 95 | 95 |
| St. Julien D. .. .. .. | — | 5 | 25 | 30 | 35 | — | — | — |
| Black Damas A. .. .. .. | — | 30 | 35 | 45 | 45 | — | — | — |
| Black Damas C. .. .. .. | — | 90 | 95 | 90 | 90 | 95 | 95 | 95 |

Considering the first seven varieties quoted, the average figures are as follows :—

| 1920 | 1921 | 1922 | 1923 | 1924 |
|---|---|---|---|---|
| 79 | 64 | 59 | 72 | 67 |

These results provide some indication of the variation which is encountered from year to year.

At the same time, Table III. shows clearly in the case of the Myrobolan, St. Julien and Black Damas selections, that considerable differences exist between the varieties of these seedling races. The above figures emphasise the importance to the propagator of exercising particular care in his choice of material of such races for nursery purposes, apart from the differences in their influence, as stocks, on scions worked upon them.

### 3.—Root Cuttings.

Many varieties of fruit tree rootstocks may be multiplied satisfactorily by the use of root cuttings. The manipulation and cultivation processes involved in this method are less troublesome and much simpler than those necessary for successful stooling or layering, and the space required for raising a given number of new plants is not widely different for any of the three methods. The chief difficulty encountered in experiments on root cuttings is in obtaining every season a sufficient quantity of suitable material, but this is obtained in a commercial nursery during routine operations of tree-lifting.

In this case the regeneration process involves the production of new adventitious shoots from root tissues. Pieces of root are embedded in soil and shoots emerge, generally from the upper cut end of the root-piece, whilst roots are also produced and the plant is re-established.

Pieces of root, from $\frac{3}{8}$ inch to 1 inch in thickness are prepared in winter and are cut in lengths of 4 or 5 inches. It is advisable, during preparation, to make an oblique cut at the end furthest from the parent stem, in order to distinguish the two ends when planting is done. The cuttings are tied in bundles and covered with damp sand until about the end of February. As soon after this as conditions permit, the root pieces are planted with a dibber, 4 inches apart, in rows 2 feet apart, with the upper ends, i.e., those cut square, just below ground level. Firm planting is necessary to ensure close contact with the soil. Apart from the usual cultivation, no further treatment is necessary until new shoots have developed and attained a length of 3 inches. At this stage many cuttings may have produced two or three shoots, and in each case these should be reduced to a single growth by the removal of the weaker ones. A large proportion of the plants are suitable in the following winter for planting out for working. Exceptionally strong plants may even be budded in the cutting rows in the first season. Fig. 7 shows a plant obtained from a root cutting and, beside it, a piece of root such as is used in the method.

### Varieties.

Although, as the figures are given below indicate, a great many varieties of rootstock may be readily propagated from root cuttings, Common Mussel plum is probably the only one to which the method, in preference to any other, is regularly applied in nursery practice in this country, whilst Northern Spy is also grown from root cuttings in the Southern hemisphere. Even in these cases fairly satisfactory results may be obtained from layers, as already stated, and in addition, hardwood stem cuttings of Common Mussel are moderately successful.

### Numbers of Plants Obtained.

Climatic conditions have a considerable influence upon the success of root-cuttings, as upon other methods of propagation, and there is but little evidence indicating what is the most suitable environment. There is some danger in a very wet spring of the root pieces rotting, whilst during very dry spells, it may happen, as with hardwood stem cuttings, that the newly developed root system is not extensive enough to supply the demands of the new shoots for water, so that wilting often occurs.

Table IV. gives results obtained with some of the varieties tested.

TABLE IV.

*Results of Trials of Root Cuttings.*

| Variety. | Percentage Rooted in Different Years. | |
|---|---|---|
| | 1 | 2 |
| *Apple Stocks :* | | |
| Broadleaf (No. I.) | 77 | 95 |
| Doucin (No. II.) | 80 | 75 |
| Jaune de Metz (No. IX.) | 60 | 70 |
| Improved Doucin (No. V.) | 62 | 60 |
| Northern Spy | 10 | 70 |
| Selected Seedlings A. | 58 | 70 |
| C. | 60 | 75 |
| H. | 73 | 80 |
| *Plums :* | | |
| Pershore | 0 | 25 |
| Brompton | 6 | 40 |
| Common Mussel | 60 | 85 |
| Common Plum | 0 | — |
| Myrobolan B. | 7 | 45 |
| St. Julien A. | — | 70 |
| Damas C. | — | 70 |

## 4.—STEM CUTTINGS.

It has already been pointed out how desirable it is to apply this method to fruit tree rootstocks. Its convenience and cheapness and the ease with which material is obtained, strongly commend it, but except for a few varieties, the desirable stocks root only sparingly from stem cuttings.

On this account, considerable attention has been given to the method during the past few years, and attempts have been made to determine, by trial and error, the conditions which influence rooting, and at the same time to investigate the principles involved in the regeneration process. It is not proposed here to give details of the large number of trials and experiments which have been carried out. The results of these have already been published in some detail (8, 9), so that it will suffice here to indicate the general lines of the work, and to give details of some of the features of particular interest.

### A. HARDWOOD CUTTINGS.

*Method.*

The usual procedure is to take, early in October, shoots of medium vigour of the current year's growth, which are cut to a length of 8 to 10 inches, the apical 4 inches or so of unripened stem being rejected. The basal cut is made just below a node and the cuttings are planted as soon as possible. If delay in planting is

unavoidable, the cuttings are bedded in sand temporarily. They are planted about 3 inches apart in rows which are about 15 inches from each other, leaving about 2 inches of each cutting above ground level. The upper three or four leaves are allowed to remain on the stems, although they are shed soon after planting. The rows are planted as digging proceeds, the trench being cut almost vertically with the spade, and a little sharp sand is placed at the bases of the cuttings. The soil is well broken up as it is placed back on the cuttings and the bases are firmly trodded before finally filling in the trench. Frequent surface cultivation is necessary throughout the season.

Callusing occurs during the first two months after planting and root production usually begins in spring, the time depending upon variety and conditions.

Plants which root are ready for planting in the nursery after one season's growth, and may be budded during the following season, as is the case with plants from stools and layers. Fig. 8 shows a plant obtained from a hardwood stem cutting.

### Conditions Influencing Rooting.

These may be considered under two groups, internal and external. Internal conditions include factors probably structural conducive or otherwise to root development, and also nutrient conditions, whilst external factors include soil and weather conditions.

It has already been pointed out that the internal conditions of the plant, as determined for example by age, have some influence upon the success of propagation by stools and layers, and similar remarks apply to cuttings. Considerable success is frequently reported as the result of planting old stems of apple varieties, but for practical purposes the material most easily obtainable for making cuttings is in the form of current year's shoots, and very often these come from hard pruned trees or even stools and layers. It appears likely that this vigorous type of stem is the least likely to be successful when planted as a hardwood cutting, but on account of its general availability such material has been used in most of the experiments at this Station. Further, if successfully propagated, such material gives the most satisfactory type of plant for subsequent nursery work.

There is, of course, some variation in the one-year-old stems, as a result of their growing on different portions of the plant, often under different conditions of light and moisture, and also there is naturally some variation in condition from season to season, following different climatic conditions. It is probably largely on this account that such widely different results are obtained in similar experiments at different times, although the material for any one experiment is carefully selected for uniformity.

Attempts to adjust internal conditions so that they are favourable for root production have already been described (8), but no consistently satisfactory results were obtained by introducing sugars and other substances into cuttings of apples and plums before planting, although certain other plants respond to this treatment.

The internal condition of the cutting can be changed, as already described, by etiolation, and it is found that better rooting is obtained by this procedure. Shoots which have been etiolated on stools or layers but which have failed to root, will in most cases develop a root system during the following season if planted out in the usual manner.

Although the internal condition of the cutting is an important factor in propagation, it is probable that conditions of soil and weather have even greater influence on the establishment of hardwood cuttings than on rooting from stools, layers or root cuttings.

Stem cuttings planted in October callus best when the soil is very moist during the following four to six weeks. Root production, which in general occurs in spring, is retarded and the cuttings may rot if the soil is wet during this later period. On the other hand, warm dry weather in May will frequently cause the cutting to resume stem growth before the root system is sufficiently large to supply adequate quantities of water, and wilting results.

The best results with hardwood cuttings have been obtained by planting in sand, which will not become waterlogged during rooting. In order to facilitate callus production, heavy and frequent watering is resorted to from the time of planting till the middle or end of November.

Some trials have been made to investigate the effect of the position of the basal cut, in relation to the nodes, upon rooting. It is usual to make this cut immediately below a node, but experiments with Mariana and Myrobolan B plums indicate that, although the number of cuttings eventually rooting is not materially affected, individuals in which the basal cut is about midway between nodes root more quickly than those with the cut close to a node. For example, some batches of Mariana examined before rooting was complete, showed that of the stems cut near a node 32 per cent. had rooted whilst 54 per cent. of those with an internodal cut had established themselves. In some experiments where both batches were left in place until all cuttings were rooted or dead, there was little difference in the total number rooting. Thus in the varieties tried, quicker rooting occurred when the basal cut was internodal.

### Varieties and Numbers Obtained.

Mariana plum is a variety commonly propagated by hardwood stem cuttings, and under good conditions 100 per cent. success has been obtained. This variety does not root readily from layers or stools, except from two-year-old

wood. This situation is exactly the reverse of that existing for many subjects, especially apples, which root readily from stools, but only with great difficulty from hardwood cuttings. Brompton and Myrobolan B plums also root fairly readily from hardwood cuttings, 80 per cent. success having been obtained without special treatment. Pershore and Common Mussel have rooted to the extent of 60 to 70 per cent. by planting in sand and watering heavily during the callusing period.

Such encouraging results have not been regularly obtained, although in all experiments, the watering of cuttings planted in sand has proved beneficial. Considerable variation occurs from year to year, in the percentage of cuttings rooted, and this variation is doubtless due to differences in weather conditions over the season preceding planting, and also during subsequent growth.

Only negligible success has generally been obtained with apples, although at times high percentages of rooted cuttings have been noted. It is exceedingly likely that some varieties, such as Broadleaf (No. I), which has occasionally rooted well in our soil, would be quite successful in a sandy medium with a good water supply.

Quinces are very often raised commercially from hardwood stem cuttings, and generally root freely under these conditions. Considerable differences have been recorded, however, for different varieties, and also for the same variety in different seasons. Quince C has rooted to the extent of 95 per cent., whilst from 60 to 80 per cent. success has been obtained with the other varieties.

No single cutting of several of the cherry varieties has yet rooted in these experiments, although these latter can be readily propagated from softwood cuttings.

It may be noted for comparison that 100 feet run of stool row occupies 350 square feet, a space which would accommodate over 1,000 hardwood cuttings.

B. Softwood Cuttings.

It is, of course, doubtful whether this method of propagation can be of economic value in its application to fruit tree rootstocks, except for desirable varieties which are obtained otherwise only with great difficulty. Only the nurseryman can decide this question satisfactorily, but there is no doubt of the value of the method for raising some varieties for experimental purposes.

*Method.*

Shoots of the current season's growth are taken as early as they are obtainable, and cut to a length of about 3 inches, though success has been obtained with even 2 inch cuttings. The growing tip is left intact and the basal cut is made about a quarter of an inch below a node. The cuttings are planted immediately, in sand in closed frames in a propagation house. The rows are about 3 inches apart, with 1½ inches between the cuttings in the row. Both distances may be less with small material. The temperature should be about 75°F. in the sand and 65°-70°F. in the air of the frame.

The regulation of the frame lights is very important and naturally depends entirely on circumstances. Wilting must not be permitted, and on hot days it is often necessary to shade the cuttings to avoid this. On the other hand, too much moisture will result in losses from fungal attack. Frequent watering and spraying is necessary until roots have been produced, after which the plants are potted up singly, or planted close together in boxes, and gradually hardened off through the open bench and closed frame. They are planted out and are fit for budding after a further season's growth.

Although the external conditions for softwood cuttings, represented by the closed propagation pit, are under far closer control than those for hardwood cuttings, which are planted in the open and are subject to all climatic variations, yet on the other hand the material available for treatment by the former method is liable to be much more variable than the almost " ripened " stems used for hardwood cuttings. Different shoots in the middle of the growing season are in all stages of development and maturity, and trials have shown that differences in internal conditions result in corresponding differences in rooting capacity. Consequently great care is necessary in selecting shoots to be used as green wood cuttings.

Repeated experiments with several varieties indicate that shoots in very active growth do not root so readily as those which have ceased to extend in length, and also that lateral shoots root better than leaders. At the same time, it is found that the earlier in the season the planting is done, the better are the results obtained. Further there are obvious advantages in early planting in that a longer season is available for full development of the root system.

These two facts are obviously not easy to apply to practice, since, if planting is to be done very early, then semi-lignified lateral shoots are not easily obtainable. A compromise must of course be effected, laying rather more emphasis on the condition of the shoot than on date of planting. Best results of all have been obtained with material obtained from potted plants brought under glass in February, from which suitable shoots can be obtained very early in the season, but this is hardly practicable commercially.

Unfortunately, as in the case of material for hardwood cuttings, the stems which are the most easily available, namely, those obtained from hard pruned trees or from stools, are the least likely to be successful, and it is better to obtain shoots from older trees.

Details of experiments on the condition of the shoot and the date of planting in relation to root production will be found in the paper already quoted (9).

Trials of etiolated greenwood cuttings have given even more satisfactory results than with hardwood cuttings, and much better rooting has generally been obtained when the bases of the shoots have developed in darkness (9).

After repeated trials of soils, coconut fibre and various mixtures of these

with each other and with sand, no more generally satisfactory medium than sand has been found.

Several varieties which do not root readily from hardwood cuttings have been found to be easily multiplied from softwood cuttings. Perhaps the most striking case is that of the Mahaleb cherry varieties, which rapidly rot when planted as hardwood cuttings but which have rooted to the extent of 90 to 100 per cent. as softwood cuttings. Apple stock No. XII and Common Mussel Plum have also been successfully raised by the method, whilst in almost all varieties tested, greater success has been obtained with softwood than with hardwood cuttings.

## Summary.

Concurrently with the experiments upon rootstock influence on scion, a series of trials have been carried out to determine the best methods of multiplying the fruit tree rootstocks by vegetative methods, in order to ensure the perpetuation of races with known characteristics.

Detailed descriptions are given of the various methods which have been used and of the manner in which different varieties respond to them, together with some account of the influence of external conditions and of the inherent properties of the material in determining this response.

Tables show the actual numbers of individuals of the different varieties which have been obtained in series of trials extending over twelve years.

An appendix indicates which of these methods has been most consistently successful with each of the varieties tested.

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## Appendix.

*Indicating the most satisfactory method so far found under our conditions, of propagating various rootstocks.*

| Variety. | Method. | Remarks. |
|---|---|---|
| *Apples.* Stocks : | | |
| Selected Seedlings. A.C.H. .. | Layers. | Some do not root readily in early years. |
| Northern Spy .. .. .. | Layers. | |
| Other Stocks .. .. .. | Stools. | |
| Scion Varieties .. .. .. | Layers. | |
| *Plums :* | | |
| Brussels .. .. .. | Stools or Layers. | Stools must be covered with soil before bud-break as described in text for layers. |
| Black Damas C. .. | | |
| Myrobolan B. .. .. | | |
| Mariana .. .. .. .. | Hardwood stem cuttings. | 90-100% success. |
| Pershore .. .. .. | Layers or Hardwood stem cuttings. | Irregular results with cuttings. |
| Common Mussel .. .. | | |
| Other Stocks and Scion Varieties | Layers. | |
| *Pears :* | | |
| Selected Seedlings .. .. | Layers. | |
| *Quinces :* | | |
| Weaker Varieties (A, B and C) except Fontenay (D) .. .. | Stools, and Hardwood stem cuttings. | |
| Stronger varieties (E, F and G), and Fontenay (D) | Layers. | |
| *Cherries :* | | |
| Mazzard varieties .. .. | Layers. | |
| Mahaleb varieties .. .. | Softwood stem cuttings. | Up to 100% success |

# THE ROOT SYSTEMS OF SOME TEN YEAR OLD APPLE TREES ON TWO DIFFERENT ROOT STOCKS, AND THEIR RELATION TO TREE PERFORMANCE.

By W. S. ROGERS and M. C. VYVYAN.

In the winter of 1927-8 it was decided that a further chapter in the history of Root Stock should be obtained by excavating and examining in detail the complete root systems of some ten year old trees on known root stocks, whose whole life history is known.

Though the work has by no means reached the stage of a full report, the facts that have already come to light are so interesting that it is thought worth while to issue this preliminary statement.

The present observations refer to six trees on two different root stocks, Malling Numbers I and IX. The results obtained from these two stocks show that the work is worth continuing and extending. Such conclusions as are given now must be taken as merely tentative, however. When further material has been excavated a better comparison can be made between these, and also between other root stocks.

Besides examining other root stocks on the same soil, it is hoped to investigate the development of similar stocks in other soils, and grafted with other scion varieties, treated in various ways.

## I.—Methods and Material.

(*a*) *Technique of Excavation.*—The excavation of the root system of a fair sized tree is itself no small problem. Two methods were used by the authors, with two distinct objects in view. In the first or " Skeleton " method a trench, extending the full width and depth of the root system, was dug beyond the range of the roots, and this trench was then worked across the ground occupied by the tree until the whole root system was excavated. It amounts, in fact, to a giant " bastard trenching " operation. The face of the trench was driven forward in 50 cm. (about 20 inch) sections, and as each root was carefully uncovered, its position and depth was marked on a plan and it was then bent back out of the way or else labelled and detached. In this way a complete plan of all the roots was gradually obtained, and from this plan the root system was afterwards re-constructed, hanging in mid air. (Figs. 6 and 7 are examples of these plans.) This method gives a very convincing demonstration of the appearance and extent of the root system, and also enables photographs to be obtained (e.g., Figs. 2-5). Since it takes a number of days to excavate such trees, however,

this method is not well adapted to measurement of *actual weight* of root, for drying commences as soon as a root is excavated, and the roots on one side of the tree are exposed for several days longer than those on the other side. It is also practically impossible to preserve all the finest fibre by this system.

To obtain reliable figures for the weight of root and also for accurate grading of the different sized roots, the second or " Block " method was used. In this method also a trench was driven across the area occupied by the roots, but, in this case, the earth was removed in blocks of known size and position, and the roots from each block were detached immediately and placed in an airtight tin and sent to the laboratory for washing, grading, and weighing.

The size selected for a block was a 50 cm. cube, but the top cubes were divided into three equal strata of about 17 cm. (6½ inches) each, so as to give a better idea of the vertical distribution of the roots near the surface of the ground, where they were most abundant.

Fig. 1 shows how the blocks were arranged, and how the bottom block might vary in size according to the depth of the soil.

Both methods of excavation require much care and perseverance. When it is remembered that for each tree excavated over 60 tons of soil had to be finely broken up and moved, it is not surprising that the four men engaged on the work took from seven to ten working days per tree.

(*b*) *Soil and Arrangement of Plot.*—The soil from which the trees were excavated is a free-working medium loam of the Lower Greensand Formation. The soil overlies the Kentish Rag, and this rock bed, or the layer of sandy " hassock " which sometimes occurs just above it, has formed the depth boundary of the root systems. A point that should be noted is that below the trees on Stock No. I. the solid rock occurred fairly regularly at about 150 cm.,* while its depth below the trees on No. IX. (30 yards away) ranged from 100 to 300 cm. and was about 200 cm. in most places. In places there was some loose " top stone " above the solid rock, but the roots grew freely through the soil in its crevices.

The trees were planted at 15 feet apart, yet in only ten years considerable interlacing of roots had taken place. On account of this, great care was necessary to avoid including roots of other trees. The problem was particularly acute in the case of the Block Method, for roots had to be detached before they could be traced to their source. There is, therefore, a chance that some of the roots in the outer blocks really belonged to the next tree, and also a possibility that one or two small roots may have passed beyond the area covered by the blocks and been omitted. It is hoped, however, that by dint of tracing the roots as far as possible errors have been minimised. It is also noteworthy that since

* It will be remembered that 30 cm. = about 1 foot.

the trench was worked from West to East, the problem of root interlacing was not so serious on these two sides; for the whole of the soil into which the roots might go on the West and East sides would be moved in the course of excavating the previous or the next tree. Also the trees on No. I were on the North headland of the plot, so in this case there was no root interference from the North side. What effect, if any, this absence of root competition on the North side of these trees has had upon the root system cannot be stated definitely at present.

The whole plantation was interplanted with black currant bushes which had just previously been pulled up by the horse and chain method. The elimination of these roots, particularly the smaller ones, also called for care. Black currant roots frequently occurred more than 5 feet below ground level.

(*c*) *Technique of Washing, Grading and Weighing.*—On arrival at the laboratory, the roots from each separate tin were carefully washed free from soil, subdivided for convenience into single lengths, then grouped into grades and weighed to .1 of a gm.; thus the actual weight of each grade of root excavated from each separate block of soil was determined. The grader used consisted of a row of pegs driven at fixed intervals into a board; the distances between the pegs being 1 mm., 2 mm., 4 mm., 8 mm., 16 mm., 32 mm. and 64 mm. respectively. Roots that would slip into the 1 mm. space were grouped as Grade I, those that would slip into the 2 mm. space but were too large for the 1 mm. space constituted Grade II, similarly Grade III consisted of those less than 4 mm. in thickness but not less than 2 mm., Grade IV those less than 8 mm. and not less than 4 mm., Grade V of those less than 16 mm. but not less than 8 mm., Grade VI of those less than 32 mm. but not less than 16 mm., and Grade VII of those less than 64 mm. but not less than 32 mm.; no roots of a higher grade than VII were met with. Where the two ends of a tapering root belonged to different grades, the root was divided at the point where the change in grade occured and the two portions placed in their correct grades. Care had to be taken to ensure that the roots were, as far as possible, in a comparable condition at the time of weighing. Preliminary tests showed that the best period of exposure between washing and weighing was about an hour; when exposed for a shorter period there is still some moisture clinging to the surface of the roots and this may vary in amount from grade to grade of root, whilst exposure for more than an hour involves a partial drying out of the roots and the smaller roots lose relatively more of their weight than the larger ones do. This possible source of error could have been avoided by using dry weights instead of fresh weights; this, however, was impracticable, since, for comparative purposes the dry weights of the bulky stems would have been required also and we had no means at our disposal for obtaining these; moreover only fresh weights were on record in the case of the prunings and fruit.

(*d*) *Variety and Root Stocks Examined.*—Six trees were excavated in the winter of 1927-8. The trees were Lane's Prince Albert, one of the weaker growing varieties of cooking apple. They were planted as maidens in Spring, 1919. The first tree lifted was a trial for the development of technique. Of the others two trees on Stock Number IX and one on Number I were excavated by the Block method, and one each on Number IX and Number I by the Skeleton system. Number I (Broadleaved English Paradise) is a vigorous stock which makes a fair sized tree of Lane's Prince Albert. Number IX (Jaune de Metz Paradise) is a very dwarfing stock, which makes small precocious trees. The average height of the ten year old trees on Number I was 8 ft. 9 in., and on Number IX, 6 ft. 6 in., and the average spread 11 ft. 6 in. for Number I, and 10 ft. 6 in. for number IX.

## II.—Discussion of Observations.

*a.* Qualitative. (*Trees excavated by Skeleton method.*)

The qualitative and quantitative results are for convenience discussed separately, but the paragraphs *a.* (1), (2), and (3), each have their counterpart in *b.* (1), (2), and (3), below, and reference should be made from one to the other.

(1) *Amount and Spread of Root.*—Figs. 2 to 5, which are photographs of the trees excavated by the Skeleton method, give a fair idea of the branch and root growth produced by the two different stocks. The white strings represent the ground level. In the case of the Number I they form 1 metre squares. The total length of the white measuring rod is 11 ft. (3.35 metres). In each case the West side of the tree is nearest to the camera.

The large amount and spread of the Number I root system can be compared with the smaller amount of root of the Number IX in Figs. 2 and 3; these also show the strong upright growth of the branches on Number I, and the weaker more spreading branches on Number IX.

(2) *One-sidedness of Root Systems.*—The horizontal distribution of the roots of the trees illustrated is seen in the actual root plans in Figs. 6 and 7. Besides the much larger area of the root system of Number I the one-sidedness of both root systems, particularly the Number IX, can be seen. (See also II. *b* (2) below and Fig. 10).

It is not at all clear why the roots have grown more profusely and farther in some directions than in others. There is nothing to indicate that roots tend to go, say, South for sunshine, for the direction of the main body of roots has varied from tree to tree.

Slight variations in the soil, and chance distribution of roots when a tree is planted, may account in part for the one-sidedness. It will be noted from

the plans, however, that some roots have turned completely round through two right angles or more, so it is evident that a root by no means always continues in the direction in which it has started. It does not appear that a root will necessarily avoid soil already occupied by another root, for in many cases several roots were found growing almost alongside. Sometimes when a root branched the two branches grew along together for some distance, which seems to indicate that some particularly congenial condition may have occurred in certain veins of soil, though no difference was apparent to the eye.

(3) *Depth and Distribution.*—The great depth to which the Number IX root system extended can be seen well in Figs. 3 and 5. Figs. 2 and 4 show the shallower distribution of the Number I.

Two interesting points, illustrated by these photographs, are the manner in which most of the main roots remain nearly horizontal or slope gently downwards or upwards in the upper 50 cm. or so of soil; and the way in which other roots of varying sizes strike vertically down from these scaffold roots. In the trees excavated, these vertical roots frequently went right down to the rock, or the "hassock" above it, and then grew horizontally along it even at a depth of 200 cm. (about 6 ft. 6 in.) or more. Both root systems show this combination of horizontal and vertical roots to a certain extent, but the vertical roots are particularly prominent in the case of the Number IX. At one point they penetrated to a maximum depth of 296 cm. (over 9 ft. 6 in.). Vertical roots often grew down worm burrows. No tap roots were found in the trees excavated. The roots entirely avoided growing in the hassock, although it is loose and friable, over two-thirds sand; but a heavy clay-like soil which occurred just next to the hassock was thoroughly permeated by the fine rootlets.

Further information with regard to the depth of rooting is provided on the plans, (Figs: 6 and 7). Numbers placed beside the roots on the plans indicate the depth (in centimetres) below ground level of the root at that point. A study of these will show how the deep and shallow roots were situated. Wherever possible the numbers are placed above or to the right of the roots to which they refer. The small circles indicate the spots where roots went vertically downwards, and the numbers beside the circles show the upper and lower limits of the vertical root. The thickness of the lines cannot be taken as a very accurate guide to the thickness of the roots, which varied from about 50 cm. to less than $\frac{1}{2}$ cm.

Besides the scaffold and vertical roots, there were numerous fibrous branch roots which grew in all directions, including vertically upwards, in both root systems. Every root ended up in fibre. Even when a root near the surface was cut by cultivation, the blunt end developed a little fibrous tuft. There was a particularly large amount of fibre immediately surrounding the trunk of the

Number I (Fig. 4). Much of the fibre is seen hanging vertically downwards in the photographs, but in reality it would be spreading in all directions.

It is unfortunate that the photographs do not show the roots more clearly, but the windy weather made the roots move so much that it was very difficult to get them still enough to photograph at all. A 50 mile an hour gale occurred immediately after the Number IX root system was re-constructed. In future it is hoped to obtain the use of a building sufficiently large for the arranging and photographing of root systems under cover.

(4) *Branch Spread.*—The dotted lines on the plans (Figs. 6 and 7) represent the approximate spread of the branches. It is clear that even in the dwarf trees the roots spread considerably farther than the branches. No evidence has been found from the trees excavated to support the idea that the root system forms a reflection of the branch system in either direction, spread, or depth. In fact, in these particular trees, the squat headed spreading trees on Number IX had very deep root systems, while the tall upright trees on Number I had root systems which were distinctly shallower, and extended relatively much farther than the branches, as can be seen from the photographs and plans. (Figs. 2-7.)

A rough numerical expression of this contrast can be given as follows :—

| Average | Number I. | Number IX. |
|---|---|---|
| | ft. in. | ft. ins. |
| Height of branches .. .. | 8 9 | 6 6 |
| Depth of rooting .. .. | 5 0 | 7 6 |
| Branch spread .. .. .. | 11 6 | 10 6 |
| Root spread .. .. .. | 20 0 | 15 0 |

These figures are of course merely averages of the few trees examined, and are not intended as a generalisation.

*b.* Quantitative. (*Trees excavated by Block method.*)

The knowledge gained from the trees dug up by the " Block " method confirms and amplifies the general impressions got from those dug up by the " Skeleton " method. Three trees in all were dug up by this method ; the scion in each case was Lane's Prince Albert, but the root stock in one was No. I and in the other two, No. IX. The exact weight of each grade of root found in every one of the 600 or more blocks excavated per tree was determined ; these values cannot be set forth here in full, but they have been summarised in various ways to show the main points of interest.

TABLE I.

*Actual and Relative Weights of Roots of Different Grades.*

| | Actual Weights. | | | Percentages. | | |
|---|---|---|---|---|---|---|
| Rootstock No. .. .. | I. | IX. | | I. | IX. | |
| Row .. .. .. .. | 1 | 7 | 7 | 1 | 7 | 7 |
| Tree .. .. .. .. | 3 | 1 | 3 | 3 | 1 | 3 |
| Grade | gms. | gms. | gms. | % | % | % |
| I < 1 mm. .. | 1,963 | 628 | 808 | 14.0 | 13.3 | 13.3 |
| II. 1 mm. < 2 mm. .. | 1,576 | 583 | 1,107 | 11.2 | 12.4 | 18.1 |
| III. 2 mm. < 4 mm. .. | 1,574 | 597 | 884 | 11.2 | 12.5 | 14.6 |
| IV. 4 mm. < 8 mm. .. | 2,258 | 1,203 | 1,013 | 16.1 | 25.4 | 16.5 |
| V. 8 mm. < 16 mm. .. | 2,667 | 927 | 924 | 19.0 | 19.5 | 15.3 |
| VI. 16 mm. < 32 mm. .. | 2,425 | 649 | 782 | 17.3 | 13.7 | 12.8 |
| VII. 32 mm. < 64 mm. .. | 1,568 | 152 | 575 | 11.2 | 3.2 | 9.4 |
| Total .. .. .. .. | 14,031 | 4,739 | 6,093 | 100.0 | 100.0 | 100.0 |

(1) *Amount and Spread of Root.*—The total weight of each grade of root and of the whole root system is given for each tree in Table I. The whole root system of the Number I, weighed 14,031 grammes (about 31 lbs.), those of the two Nos. IX weighed 4,739 grammes (about 10½ lbs.) and 6,093 grammes (about 13½ lbs.) respectively. The root system of the No. I was thus more than twice as heavy as that of one of the Nos. IX and almost three times as heavy as that of the other. The percentages of the total root weights that belonged to each grade are given in this same table; there are no obvious and consistent differences in these values for the two types of root stock. It will be seen that the Number I had 14 per cent. of fibre, and each Number IX 13.3 per cent., but from observed differences in the habit of growth of the two root systems it is considered that comparison on such a basis is not justified.

The horizontal spread of the No. I root system is shown clearly by Fig. 8, A, B and C. These represent bird's-eye views of the root systems of the three trees dug up by the Block method, they should be compared with the plans (Figs. 6 and 7) obtained from similar trees excavated by the Skeleton method. Each of the small squares into which the figures are divided represents the cross section (50 cm. × 50 cm.) of one of the vertical columns of blocks extending down from the surface of the soil to the level of the rock.

The values 1718 and **63** etc. written in each square, denote the weights (in grammes) of the total root and of fibre respectively found in the corresponding columns of blocks. Apart from the greater spread of the Number I root system, certain other facts of interest seem to be indicated. In all three trees the root system appears to be somewhat irregularly distributed about the centre of the

tree, but the weight of root per vertical column of blocks seems to fall off fairly consistently as they pass towards the outskirts of the root system. Both the irregularity in distribution and the falling off in weight are less pronounced in the case of the fibre than in that of total root weights. It is hard to tell from these rather complicated figures if these features are more marked in one type of root stock than in the other; the data have, therefore, been summarised in Figs. 9 and 10 to throw further light upon these points.

The relative amounts of roots at different distances from the centre of the tree are shown in Fig. 9, A, B and C. The three squares of increasing size represent the regions bounded by heavy lines in Fig. 8. Thus the central square represents the region of soil composed of the four central columns of blocks; it represents therefore a column of soil 1 metre (about 3 ft. 3 in.) square in cross section, at the very centre of the tree. Similarly the next square represents a hollow column of soil 3 metres (about 10 ft.) square in cross section surrounding this central column; a glance at Fig. 8 will show that this region is made up of thirty-two vertical columns of blocks. The outer square represents the hollow column of soil 5 metres (about 16 ft. 4 in.) square in cross section surrounding the 3 metre column. The values written in each square denote the percentages of the total root system and of the total fibre respectively that occur in the successive regions. Thus in the Number I tree, Fig. A, the sum of the total weights of roots occurring in the four central columns of blocks is 4,662 grammes (i.e. 1,718, 1,150, 951 and 823), this is 33 per cent. of 14, 031 the total weight of the tree.

These figures show that there was no marked difference between the two types of root stock in the *relative* amounts of roots at different distances from the trunk, but they reveal some facts of considerable interest common to all the trees, which seem to have a bearing upon manurial practice.

Although in each case about a third of the total mass of the roots occurred in the column of soil about a yard square in the centre of the tree, only 10-12 per cent. of the fibre occurred in this region; and it is the fibre rather than the total root weight that must be regarded as the best available measure of the "feeding root system." From 36 to 49 per cent., according to the tree, occurred in the fringe of soil more than five feet from the trunk of the tree. This suggests that the common practice of putting the bulk of manures near the trunk of a tree has little to commend it.

(2) *One-sidedness of Root Systems.*—Fig. 10, A, B and C, give the percentage of total root and of total fibre respectively that occurred in each of the four quarters (N.E., N.W., S.E. and S.W.) of the root systems. These figures show clearly that the unevenness in distribution was more marked in both the Numbers IX than in the Number I; the percentage of total root per quarter

TABLE II.

*Depth of Rooting.*

| Depth: Layer of Soil between depths of:— | Number I. Row 1. Tree 3. | | | | | | Number IX. Row 7. Tree 1. | | | | | | Number IX. Row 7. Tree 3. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % in Layer | % Above and Below depth of:— 17 cm. | 33 cm. | 50 cm. | 100 cm. | 150 cm. | % in Layer | % Above and below depth of:— 17 cm. | 33 cm. | 50 cm. | 100 cm. | 150 cm. | % in Layer | % Above and below depth of:— 17 cm. | 33 cm. | 50 cm. | 100 cm. | 150 cm. |
| 0—17 cm. | 12<br>**21** | 12<br>**21** | | | | | 9<br>**10** | 9<br>**10** | | | | | 7<br>**18** | 7<br>**18** | | | | |
| 17—33 cm. | 61<br>**33** | | 73<br>**54** | 81<br>**63** | | | 40<br>**14** | | 49<br>**24** | 60<br>**33** | | | 40<br>**15** | | 47<br>**33** | 67<br>**44** | | |
| 33—50 cm. | 8<br>**9** | | | | 93<br>**84** | | 11<br>**9** | | | | 85<br>**69** | | 20<br>**11** | | | | 82<br>**67** | |
| 50—100 cm. | 12<br>**21** | | | | | 100<br>**100** | 25<br>**36** | | | | | 97<br>**93** | 15<br>**23** | | | | | 95<br>**89** |
| 100—150 cm. | 7<br>**16** | 88<br>**79** | 27<br>**46** | 19<br>**37** | 7<br>**16** | | 12<br>**24** | 81<br>**90** | 51<br>**76** | 40<br>**67** | 15<br>**31** | | 13<br>**22** | 93<br>**72** | 53<br>**67** | 33<br>**56** | 18<br>**33** | |
| 150—200 cm. | | | | | | 0<br>**0** | 3<br>**7** | | | | | 3<br>**7** | 5<br>**11** | | | | | 5<br>**11** |

Percentages of Total Root Weight and total fibre in each layer of soil. (Fibre in heavy type.)

varying from 12 per cent. to 35 per cent. in one Number IX and from 15 per cent. to 42 per cent. in the other, whilst the greatest variation in the Number I was from 19 per cent. to 32 per cent. This is in general agreement with the impression, gained from the trees excavated by the Skeleton method, that the root system of the Number IX tree is more lop-sided than that of the Number I. It will be observed, too, that in every case the distribution of fibre was more uniform than that of the roots taken as a whole.

(3) *Depth of Rooting.*—The most striking and unexpected difference found between the two types of root stock lay in their relative depth of rooting. Both the Numbers IX were more deeply rooted than the Number I ; this is brought out clearly in Table II which gives the percentage of the total root and of the fibre of each tree found in each of the successive horizontal layers of soil. This table shows that nearly three-quarters (actually 73 per cent.) of the total root of the Number I and less than half (actually 49 per cent. and 47 per cent.) of that of the Numbers IX occurred in the upper layer of soil 33 cm. (about 13 in.) thick. This layer, moreover, contained more than half of the total fibre of the Number I, but only one-quarter or one-third of that of the two Number IX root stocks. Further, it will be seen that nearly a third of the total fibre of each of the Numbers IX occurred in the regions of soil more than 100 cm. (3 ft. 3 in.) below the surface of the ground, whilst less than one-sixth of that of the Number I was found down at those depths.

These observations appear to be directly opposed to the very common belief that the dwarfing effect of the Number IX root stock is due to its having a more shallow root system than a vigorous stock like Number I. It is possible that these differences in depth of rooting may have been due in part to differences in the depth of soil under the three trees ; the " rag " chanced to be nearer the surface under the tree on Number I than those on Number IX. In any case it is clear, however, that a dwarfed tree is not necessarily the result of a shallow root system nor a vigorous tree the result of a deep root system, for the tree on this Number I with its comparatively shallow root system showed the vigour and the delayed fruiting typical of trees on Number I, and the trees on these Numbers IX with their deeper root systems, showed the dwarfed habit and the precocity typical of trees on Number IX. One important reservation, however, must be made : these observations apply to trees ten years old, they may not apply to trees of other ages. It is possible that the Number IX may have a shallower root system than the Number I during the first few years of its life, and it is conceivable that its root system might fill out more in the upper layers of soil than in the lower, if allowed to grow to the size of that of the Number I excavated. These points can only be cleared up by investigation of root systems of both stocks of other ages and sizes.

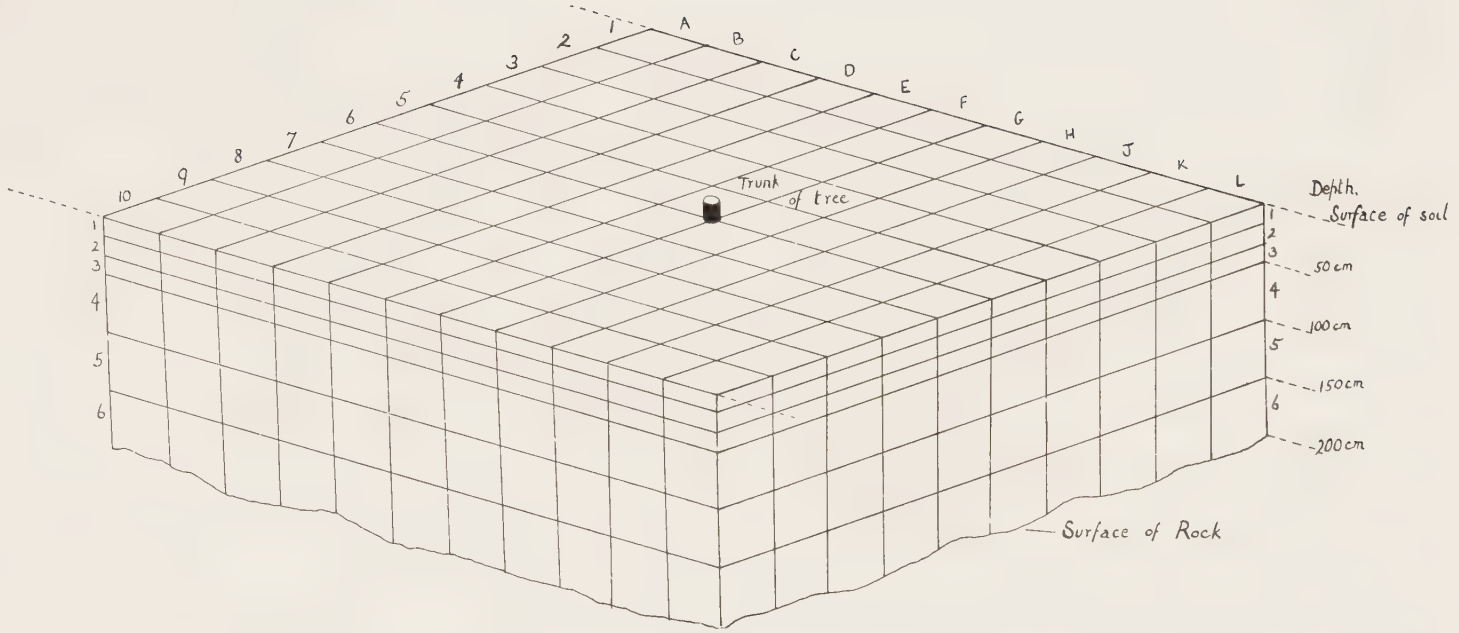



FIG. 1.

Diagram showing arrangement of Blocks in Block method of excavation.

For the sake of simplicity, this illustration is given as an isometric projection, instead of as a perspective drawing.

FIG. 2. Lane's Prince Albert on Stock Number I.

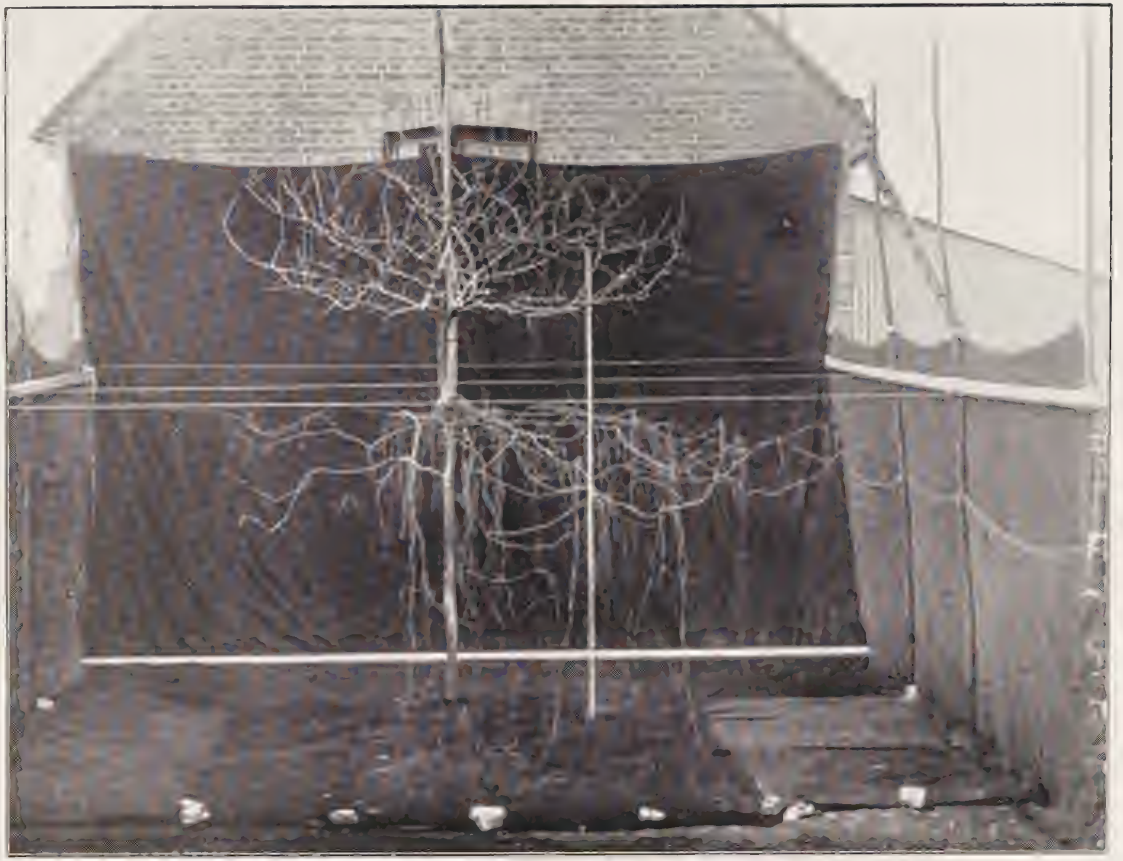


Fig. 3. Lane's Prince Albert on Number IX.

FIG. 4. Lane's Prince Albert on Number I.

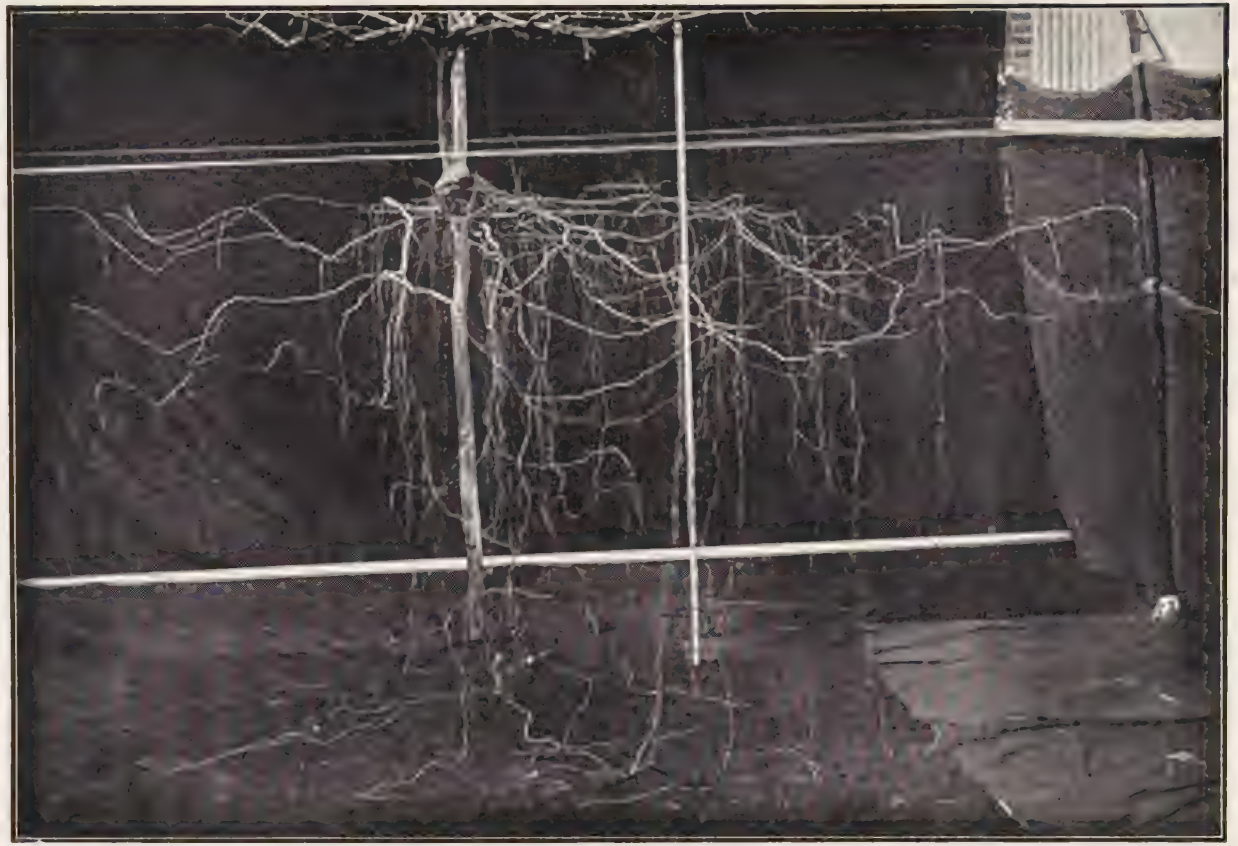
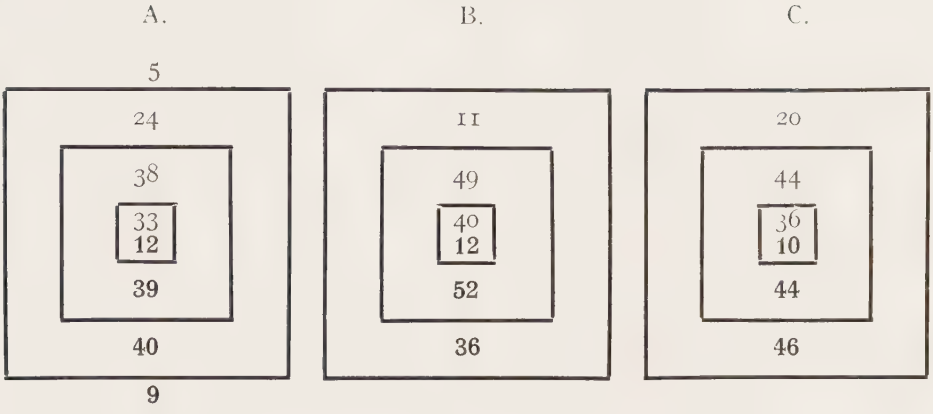


FIG. 5. Lane's Prince Albert on Number IX.

FIG. 6.

ROOT PLAN OF LANE'S PRINCE ALBERT ON STOCK NO. I. (Plot 10, Row 1, Tree 2.) The Plan is ruled in 1 metre squares. The numbers represent depth in centimetres of root below or to left. The dotted line indicates spread of branches. The circles indicate vertical roots.

Fig. 9.

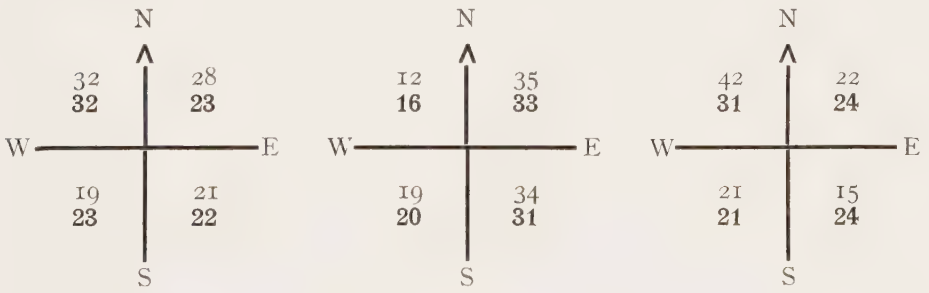



*Number I.* *Number IX.*

*Row* 1, *Tree* 3. *Row* 7, *Tree* 1. *Row* 7, *Tree* 3.

Percentage of Total Root Weight and of Fibre in Different Regions of Root System. Upper values refer to Total Root Weight. Lower Values to Fibre. (printed in Clarendon type, thus **12**). In each figure the central square represents the column of soil 1 metre (about 3 ft. 3 ins.) square in cross section, reaching from surface of soil to the rock at the centre of the tree. The next square the hollow column of soil 3 metres (about 10 ft.) square in cross section, immediately surrounding the central column. The outer square a hollow column of soil 5 metres (about 16 ft. 4 in.) square in cross section.

Fig. 10.




No. I. No. IX. No. IX.

*One-sidedness of Root Systems.*—Percentages of total root and of fibre in the four quarters of the root systems. (Fibre in Clarendon type, thus—**32**.)

FIG. 7.

ROOT PLAN OF LANE'S PRINCE ALBERT ON STOCK No. IX. (Plot 10, Row 7, Tree 2.) The plan is ruled in 1 metre squares. The numbers represent depth in centimetres of the root below or to left. The dotted line indicates spread of branches. The circles indicate vertical roots.

Fig 8

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 23<br>9 | 22<br>14 | 62<br>16 | 65<br>9 | 49<br>9 | 30<br>9 | 59<br>6 | 11<br>3 | 9<br>5 | 15<br>3 |
| | 50<br>18 | 27<br>11 | 56<br>14 | 84<br>7 | 26<br>3 | 48<br>1 | 11<br>3 | 9<br>2 | 11<br>7 | 10<br>6 |
| 19<br>3 | 29<br>17 | 65<br>26 | 67<br>13 | 153<br>10 | 22<br>6 | 75<br>4 | 10<br>2 | 26<br>3 | 35<br>12 | 49<br>18 |
| 6<br>3 | 58<br>11 | 58<br>15 | 54<br>16 | 123<br>14 | 196<br>10 | 62<br>9 | 33<br>10 | 32<br>6 | 40<br>13 | 97<br>16 |
| 2<br>1 | 59<br>12 | 73<br>11 | 86<br>14 | 136<br>23 | 322<br>24 | 59<br>22 | 117<br>18 | 63<br>12 | 96<br>14 | 102<br>15 |
| 5<br>2 | 63<br>17 | 165<br>23 | 116<br>24 | 197<br>29 | 411<br>47 | 181<br>27 | 227<br>30 | 168<br>14 | 46<br>16 | 35<br>14 |
| 4<br>3 | 25<br>5 | 75<br>20 | 123<br>22 | 346<br>31 | 951<br>56 | 1718<br>63 | 237<br>35 | 68<br>17 | 39<br>8 | 18<br>7 |
| 2<br>2 | 9<br>6 | 24<br>10 | 104<br>28 | 210<br>39 | 823<br>52 | 1150<br>64 | 190<br>31 | 74<br>24 | 17<br>10 | 12<br>8 |
| 12<br>5 | 22<br>5 | 28<br>7 | 27<br>12 | 117<br>24 | 361<br>37 | 311<br>27 | 92<br>24 | 113<br>18 | 53<br>10 | 11<br>6 |
| 11<br>3 | 36<br>10 | 66<br>16 | 107<br>16 | 58<br>19 | 171<br>18 | 210<br>32 | 154<br>20 | 78<br>11 | 33<br>13 | 22<br>7 |
| | 15<br>8 | 46<br>21 | 48<br>11 | 127<br>15 | 67<br>10 | 70<br>27 | 108<br>13 | 62<br>12 | 31<br>11 | 13<br>6 |
| | 32<br>15 | 52<br>23 | 40<br>14 | 44<br>18 | 29<br>14 | 36<br>9 | 44<br>15 | 57<br>11 | 56<br>17 | 21<br>10 |

A.

Number I. (Row 1, Tree 3.)

Fig. 8. Horizontal Spread of Roots.

The small squares represent columns of soil, 50 cm. square in cross section, extending vertically down from the surface of the ground to the solid rock. The upper value in each square denotes the total weight, in grammes, of roots found in that column ; the lower value denotes the number of grammes of fibre (roots less than 1mm. in diameter) in the column. The large squares, heavily outlined, correspond to the squares in Fig. 9.

The North side of the tree is in each case at the top of the page.

## III.—Relation of Root to Tree Performance.

### Table III.

### Summary of Performance of Trees.

*Lane's Prince Albert planted as maidens on Plot* 10 *in Spring*, 1919.

| Rootstock | Number I. | Number IX. | |
|---|---|---|---|
| Row | 1 | 7 | 7 |
| Tree | 3 | 1 | 3 |
| | gms. | gms. | gms. |
| (*a*) Weight of branches and trunk when lifted, January, 1928 | 27,100 | 12,200 | 14,050 |
| (*b*) Weight of prunings to date | 4,590 | 1,701 | 2,480 |
| (*c*) Total Stem growth weight | 31,690 | 13,901 | 16,530 |
| (*d*) Total Root, January, 1928 | 14,030 | 4,739 | 6,093 |
| (*e*) Total stem and root | 45,720 | 18,640 | 22,623 |
| (*f*) Total weight of Fruit | 77,600 | 58,600 | 71,900 |
| | | Ratios. | |
| (*g*) $\frac{c}{d}$ $\frac{\text{Total Stem}}{\text{Root}}$ | 2.25 | 2.94 | 2.72 |
| (*h*) $\frac{a}{c}$ $\frac{\text{Stems (as lifted)}}{\text{Root}}$ | 1.93 | 2.58 | 2.30 |
| (*j*) $\frac{f}{e}$ $\frac{\text{Fruit}}{\text{Total Tree weight}}$ | 1.70 | 3.14 | 3.18 |
| (*k*) $\frac{f}{d}$ $\frac{\text{Fruit}}{\text{Roots}}$ | 5.50 | 12.4 | 11.8 |
| (*l*) $\frac{f}{c}$ $\frac{\text{Fruit}}{\text{Total Stems}}$ | 2.45 | 4.22 | 4.34 |

In Table III. a summary is given of the stem, roots and fruit which each tree has produced during its whole life. The relations between these various activities are shown in the ratios in the lower half of the table.

Although the total weight of the Number I tree is more than twice that of either Number IX tree (see e. in table) the difference in ratio of stem to root (*g*) is not sufficiently marked to be regarded as significant.

Comparing the weight of fruit with weight of root, however, we find considerable differences between the two stocks. The weight of the fruit produced by the Number I was only five and a half times that of the roots, whilst both No. IX's had produced about twelve times as much fruit as root (see k).

Further evidence pointing the same way was provided by the tree on Number I excavated by the "Skeleton" method. The roots were cut off this tree and weighed after the photograph had been taken, and the ratio of fruit to root weight was found to be 3.3 which is a value of the same order as that for the other tree on Number I: moreover, the value for the weight of roots for this

tree was probably an underestimate as they had inevitably been exposed for some considerable time to loss in weight by drying out of their moisture. The true value for the ratio was probably lower than that given.

It is of interest to note that the total fresh weight of fruit produced by a tree in ten years was far greater than the total fresh weight of stems and roots produced in the same period.

This preliminary work has shown that the whole question of root performance of fruit trees should amply repay much further investigation.

The authors are much indebted to a number of members of the Staff—notably Miss A. D. Mackenzie and Miss I. D. Skinner—who rendered valuable assistance in the large amount of tedious work involved in this investigation.

## Summary and Conclusions.

(1) Six ten-year old trees of Lane's Prince Albert, of known life history, growing on the Lower Greensand over Kentish Rag, were dug up during the winter 1927-8.

(2) The root systems of three of these trees, two on Malling Number I (vigorous) and one on Malling Number IX (very dwarfing) were excavated intact, as far as possible. Plans were made of the distribution of the roots as they were exposed, and photographs afterwards taken of the reconstructed root systems.

(3) Three trees, two on Number IX and one on Number I, were dug up by the removal of blocks of soil of known size and position. The roots from each block were graded and weighed at once.

(4) None of the trees had a tap root ; the root system of each was composed of a scaffolding of roots running more or less horizontally near the surface of the soil ; from these numerous vertical roots descended at all distances from the trunk, frequently following worm burrows. The depth limit was set by the rock or the sandy " Hassock " layer just above it ; the roots did not enter this but turned horizontally and formed much fibrous root in the clayey layer just above.

(5) The root system of the Number I was two to three times as heavy as that of the Number IX and spread out farther from the trunk ; it did not descend so deeply but this may have been partly due to the soil happening to be shallower under the Number I trees than under the Numbers IX. Three-quarters of the Number I root system and only half that of the Number IX occurred in the upper 13 inches of soil.

(6) Fibre (roots less than 1 mm. diameter) occurred everywhere, growing in all directions including vertically upwards ; every root ended in fibre. The proportion of fibre to total root was 14 per cent. in the Number I and 13.3 in the Number IX.

(7) Only some 10 per cent. of the fibre occurred in the region one yard square at the centre of the tree ; the roots extended considerably farther out than the branches of the trees and some 40 per cent. of the fibre occurred in the outer part of the root system, more than $2\frac{1}{2}$ yards from the trunk. This suggests that it is not a good practice to place manure mainly near the trunk of a tree.

(8) The ratio of stem to root was about the same in both stocks, but that of fruit to root was more than twice as great in Number IX as in Number I.

The total fresh weight of fruit produced in ten years was in each case greater than the total fresh weight of stem and root.

# THE NORTHERN SPY APPLE AS A ROOTSTOCK

By R. G. HATTON.

The Northern Spy has for a considerable time occupied a somewhat unique position in the apple industry of certain countries. Although in parts of the United States of America the orchardist plants this variety in quantity in anticipation of the high class fruit which is produced at long-last, its main distinction does not rest upon its well deserved reputation as an apple of good quality, but upon its proved immunity to the attacks of Woolly Aphis (*Eriosoma lanigerum* Hausm) or American Blight. Both long observation and careful scientific tests (1 and 2) have now shown that whilst apple varieties exhibit very different degrees of susceptibility and response to the attacks of this Aphis, very few can be classed even as resistant, and, up to the present, those which possess a degree of immunity (in both stem and roots) comparable to "Spy" are still more rare.

The seriousness of the pest in certain countries (Australia, New Zealand and South Africa), and the nature of its life cycle, brought about the very general adoption of Northern Spy as the supplier of an immune root system, and main stem, upon which to graft varieties which were more certain bearers yet more susceptible to Woolly Aphis attack. The use of Northern Spy as a rootstock has become so much the accepted practice that, whilst overseas fruit growers visiting this country not infrequently express surprise at the apparent supineness of English Nurserymen for not adopting it, they fail to realise that it takes a number of attributes to make an ideal rootstock, and that, under many conditions, immunity to Woolly Aphis may not be the most important.

In this country, Northern Spy would have to pass several other tests before it were widely adopted, and, even then, in the light of modern knowledge upon the economic use of rootstock influence to control the size and cropping of the tree, no single rootstock could fill the requirements of the progressive grower. It has now been proved that, by judicious use of the non-immune rootstocks in circulation in Western Europe, it is possible to obtain trees of a single variety in significantly different sizes and with significantly different inherent qualities for cropping, etc. The economic advantages of interplanting such standardised material, and of planting the particular tree most suited for its specialised purpose, would be lost by the universal adoption of any single rootstock, just as it is lost by the indiscriminate use of seedling rootstocks.

Whilst it would indeed be a great advantage to minimise in both the English Nurseries and Orchards the risk of Woolly Aphis attack, in most localities and under most conditions its proportions do not warrant the surrender, on that account alone, of the valuable series of rootstocks now in use.

Even then, maybe the performance of the Northern Spy would justify its selection to replace a non-immune stock of similar potentialities within that series. The same criteria then must be applied to Spy as have been applied to other selected rootstocks at East Malling, if its adoption is to be recommended.

First, what has been its performance in the Nursery ?

Although Spy has never been successfully raised here by the ordinary stooling method, and cannot be regarded as one of the ready rooting apple stocks, the adoption of mound layering, and the etiolation (by a thin covering of earth) of the buds before they start to grow, have resulted in the production of an average of 70 per cent. rooted one year shoots. These shoots generally root only towards the base and require to be severed carefully from the parent stool, but a large percentage of these stocks are fit for budding in the following July, and such a method would appear to be a valuable saving of time and labour over the two year process of bench-grafting a piece of " Spy " stem on to a piece of " Spy " root, and then top working the desired variety thereon a twelvemonth later, a process which seems in very general use overseas.

Under the prevalent soil and climatic conditions at East Malling (low summer and total rainfall, without artificial irrigation), " Spy " has been very susceptible to the Powdery Mildew of the Apple (*Podosphaera leucotricha*), both in the Nursery row and as a variety grown for fruiting. In the former case, it is, from the point of view of infection, almost as undesirable an attribute in the nursery as susceptibility to Woolly Aphis.

Secondly, does " Spy " produce a good marketable maiden (one year) tree ?

Although it cannot be claimed that it has been used extensively here, sufficient information is to hand to say that by comparison with many of the other rootstocks in common use it does not produce on the average an outstanding maiden tree, nor has it taken the bud any too satisfactorily. Indeed the bud wound has often failed to heal satisfactorily under nursery conditions here.

Finally, what has been its performance in the plantation in producing a good standard or bush tree ?

For the purpose of making a comparative test at East Malling, two separate trials have been planted in two widely separated situations on the Station. In both cases the scion variety was Grenadier. This selection was made deliberately for two reasons. Grenadier is a good indicator of rootstock effect, and exhibits preferences readily. On a rootstock which suits it, Grenadier develops into a large orchard tree ; on one which does not, it develops into an unthrifty leaf scorching bush. It was also hoped to obtain a fairly rapid answer to the trial, since Grenadier is normally a quick cropping variety.

The rootstock trials at East Malling have emphasised the fact that varietal peculiarities and partialities render wide generalisations about stock suitability

impossible, and that an exhaustive series of combinations of stock and scion are at present necessary in order to be sure of the correct answer in each individual case. At the same time they have indicated that there are significantly differing groups of rootstock which generally affect the scions worked thereon in the particular direction of dwarfingness and precocious bearing or the reverse (4). The trials planned to compare the effect of Spy as a rootstock with representatives of these groups were merely designed to answer the question to which group does Spy belong.

The following rootstocks, amongst others, were selected for the comparative trials with Spy.

(a) *Very Vigorous Group.* Bristol O.F.5 and Malling No. XVI.

(b) *Vigorous Group.* Broadleaved English Paradise (Malling No. I).

(c) *Semi-dwarfing Group.* Doucin (Malling No. II).

All these stocks, together with Northern Spy, were uniformly budded with Grenadier, one series in the summer of 1920 and the other in 1921. It was quite anticipated that Spy would belong to Group (a), and therefore it was decided in the first trial to run up the trees in the nursery to 3 ft. 6 in. before heading—for half standard trees. In the second trial, they were planted out as Maidens and cut back as bushes at 2 ft.

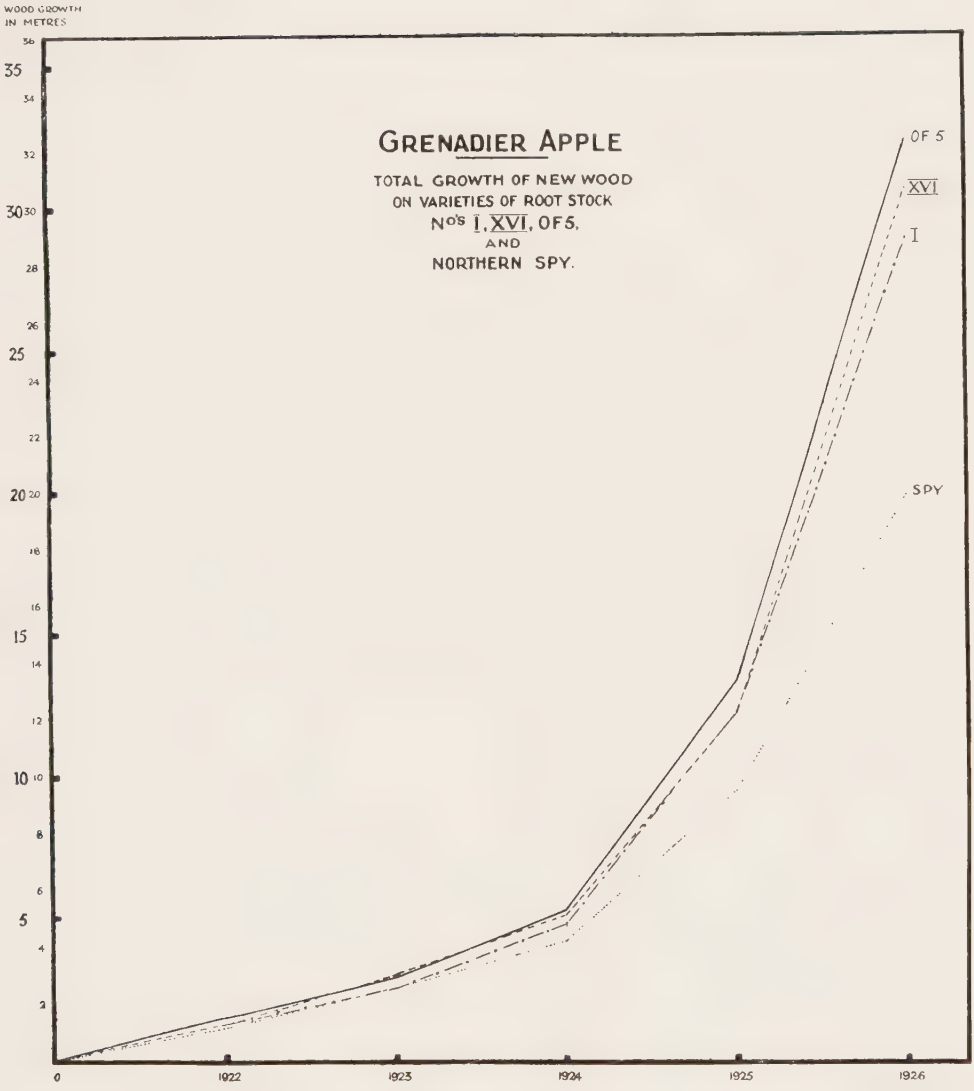
Unfortunately very few of the trees on Spy stock reached the required height of 3 ft. 6 in. within the allotted period (two years), and it was only possible to select seven half standard trees to compare with the units of ten to twelve, which it was possible to obtain of trees on O.F.5, and Nos. XVI and I. Since Doucin No. II is recognised as generally unsuitable for half standard purposes it was not included in this first trial, but reserved only for the bush test.

In this latter trial, units of nine trees each of O.F.5, Doucin (II), and Northern Spy were planted out for bush trees.

In neither trial was the arrangement of the trees strictly random. In the Half standard trial, the units were divided into two blocks and repeated consecutively over the ground—the trees being 30 ft. apart with a bush tree of another variety interplanted. In the Bush trial, the trees were alternated in two parallel rows 12 ft. apart in the rows, and 12 ft. between the rows. In both series, uniform methods of pruning, spraying and cultivation were adopted.

The half standard trees had annual measurements of all new wood growth taken from the time of heading back (1922), until the end of 1926. At the time of planting out the average weights of the two year feathered trees were as follows :

| | | | | | |
|---|---|---|---|---|---|
| On rootstock | O.F.5 | the average | weight in ozs. | was | .. 16 |
| ,, | No. XVI | ,, | ,, | ,, | .. 13 |
| ,, | No. I | ,, | ,, | ,, | .. 15 |
| ,, | Northern Spy | ,, | ,, | | .. 11 |


WOOD GROWTH IN METRES
GRENADIER APPLE
TOTAL GROWTH OF NEW WOOD ON VARIETIES OF ROOT STOCK
NOS I, XVI, OF 5,
AND
NORTHERN SPY.
OF 5
XVI
I
SPY
0
1922
1923
1924
1925
1926

The following table shows the comparative vigour of the trees on the four rootstocks :—

*Average Total Wood Growth (for five years) of Grenadier Half Standard Trees on Various Rootstocks.*

| Rootstock. | No. of Trees. | Mean Growth in Metres. | Standard error. |
|---|---|---|---|
| O.F.5. .. | 10 | 32.37 | *1.306* |
| No. XVI .. | 12 | 30.62 | *1.160* |
| No. I (Broadleaf Paradise) | 12 | 28.89 | *0.846* |
| Northern Spy .. | 7 | 19.94 | *1.223* |

The Means which do not differ significantly are enclosed in brackets.

The very great difference in vigour between the Broadleaf English Paradise (No. I), and Northern Spy, under the normally favourable conditions for growth at East Malling, where trees even on the very dwarfing Jaune de Metz Paradise make exceptionally good development, is instructive.

There is every indication that this is not a case of the slower recovery of Spy after transplanting, but a definite lack of vigour which, as the graph shows, is accentuated with years.

After the taking of complete wood measurements upon these trees became impracticable, the girth of stem, at a fixed uniform height, was annually recorded. At the time of writing (May, 1928), the Mean Girth figure per tree in millimetres is as follows :—

| | | | | |
|---|---|---|---|---|
| On rootstock | O.F.5 | .. | 152.2 | S.E. *2.45* |
| ,, | No. XVI | .. | 148.2 | *2.11* |
| ,, | No. I | .. | 147.6 | *3.68* |
| ,, | Northern Spy | .. | 126.6 | *3.03* |

Whilst the first three stocks continue to produce creditable half standards, the Northern Spy exhibits but poor development, a fact which is also noticeable in the lack of sturdiness of branches and an apparent poverty of leaf development.

So far this loss of vegetative vigour has not been compensated for by earlier bearing. In 1926 and 1927 the trees bore a sprinkling of fruit which gives a slight indication of the relative precocity of Grenadier on these different rootstocks.

| | | | | | |
|---|---|---|---|---|---|
| The trees on | O.F.5 | have averaged | 1.8 | fruits per | tree. |
| ,, ,, | No. XVI | ,, ,, | 3.5 | ,, ,, | |
| ,, ,, | No. I | ,, ,, | 9.1 | ,, .. | |
| ,, ,, | Northern Spy | ,, ,, | 13.7 | .. .. | |

It is clear that the trees on both No. I and Northern Spy are earlier bearers than on O.F.5, or No. XVI, but the difference between Northern Spy and No. I is hardly enough to be significant. Thus whilst failing to build up as good a framework as No. I in seven years, Spy has not got to its credit a much better crop though it undoubtedly falls into the group of semi-dwarfing rootstocks under East Malling conditions.

Whilst the trial of Bush trees still further confirms this measure of its vigour, it reveals a fact relative to its early cropping in comparison with Doucin (Malling No. II) which is at least suggestive. The following Table summarises the performance of these trees to date :—

*Average Figures for six year old bush Grenadiers on Various Rootstocks. (Units of nine trees.)*

| Rootstock. | Total mean Growth (in metres). | Girth (Spring 1928). | Total Fruits per tree. |
|---|---|---|---|
| O.F.5 .. | 51.57 | 13.57 | 0 |
| Doucin No. II .. | 42.90 | 12.51 | 13.67 |
| Northern Spy .. | 36.86 | 12.12 | 6.22 |

Whilst trees on all three stocks differ significantly in wood growth, there is no difference between the girth of trees on Doucin and Spy. However, trees on No. II have produced significantly more fruits than trees on Spy, and they actually showed signs of cropping a year earlier.

In other words, Spy, under these conditions and budded with the variety Grenadier, has proved to be a more dwarfing stock than Doucin (No. II), but has only achieved half the number of fruits.

It seems hardly necessary to go further to indicate why Northern Spy has not been widely acclaimed in this country as the universal rootstock.

Doubtless the multiplication of such empirical comparative trials, under various soil and climatic conditions, and with a series of different scions, would be valuable, but since for this country generally Woolly Aphis resistance of the stock is a highly desirable attribute rather than a prime necessity, it has been considered at East Malling a much more promising line of action to try and breed into our otherwise very desirable groups of rootstock the additional one of the immunity possessed by Spy, and so retain all the other advantages accruing from a selected series of rootstocks. How far this line promises success has been reported in detail elsewhere (2). That the character of immunity to Woolly Aphis attacks in Spy is a heritable factor, transmissible to some of its progeny when crossed with other rootstocks, is now an established fact. It remains to be seen

how far the desirable qualities of these other rootstocks are transmissible, and whether they can be combined with the specific immunity. Work is in progress along these lines.

Since it is fully realised what qualifying influences soil and climatic conditions may and do have upon rootstock action, it is not difficult to imagine that, under many overseas and even certain home conditions, the Northern Spy may be an efficient, even a highly desirable rootstock. Yet after the results detailed here, and after the many contradictory accounts of the behaviour of trees on Northern Spy roots in various parts of the Dominions, it is legitimate to speculate upon the outcome of comparative rootstock trials in some of these areas.

That there is universal satisfaction with Spy as a rootstock overseas would seem to be far from true. It would appear that, whilst under the best conditions of growth, Spy gives highly satisfactory trees, on many other soils lack of vigour is very apparent, and it has been hinted by several overseas nurserymen that many of their growers prefer to buy trees on mixed non-immune seedling rootstocks, because they thus obtain a higher percentage of vigorous trees.

That a race of seedlings, all immune to woolly Aphis attack and suitable for rootstocks, is likely to be produced in the near future is highly improbable. That when Spy is used as a parent, some of the resulting seedlings possess immunity has been proved, and the straight road to improving and widening the choice of rootstocks in Woolly Aphis infested areas would appear to be by selecting and vegetatively multiplying desirable individuals from amongst such seedlings. It is possible that the frequently established yet unfounded conviction amongst many overseas growers, that layered (or otherwise vegetatively raised) rootstocks do not produce highly vigorous trees, may be due to the fact that their experience has been limited by the use of Northern Spy, and possibly to some of the older and dwarfer forms of so-called Paradise, from Europe. At any rate under East Malling conditions, many other vegetatively raised rootstocks have far outstripped Spy in vigour, whilst Spy, though obviously belonging to the more precocious bearing groups of rootstock, has not surpassed the Doucin (No. II), or even the Broadleaved English Paradise (No. I), in that respect.

From the Investigator's point of view, several further facts about the behaviour here of Northern Spy are worth chronicling, if only to illustrate the complexity of the rootstock problem and the inter-relationships of root and stem.

Though Spy makes a large vigorous tree when it does well (3), the specimen growing on its own roots in the arboretum (now fifteen years old) has only made a tree of 3.5 metres in height and 2.7 metres at greatest spread.

Though this tree was transplanted at seven years old it has never blossomed. Fifty-two young trees of Northern Spy have been worked on the very precocious Jaune de Metz (No. IX) Paradise Stock, on which most of the varieties tested,

including slow bearers such as Blenheim Orange, blossom in the second year, have up to the end of their third possible blossoming season produced but a single truss of flowers amongst the whole group. Yet Northern Spy as a root-stock has induced early blossom production upon Grenadier. Spy is described as being very late to come into flower, but there is no record here of it thus affecting the flowering period of Grenadier.

Finally, although Northern Spy has a notably erect branch system, the root system of Spy under these conditions, although strong, has been notably horizontal and spreading and lacking in deep roots, at any rate in the early years.

The writer is indebted to the Propagation and Recording Staff for all the care taken in raising the material and keeping it under observation. Special thanks are due to Miss A. D. MacKenzie for summarising the records and to Mr. T. N. Hoblyn for examining them statistically, indicating the significant differences between means and preparing various diagrams. As usual the investigation is the outcome of the co-operative effort of many Members of Staff.

## Summary.

The growth and early cropping of the variety Grenadier is compared when budded upon Northern Spy, and semi-dwarfing, vigorous and very vigorous layered rootstocks.

Under East Malling conditions, Spy would be classed as a semi-dwarfing rootstock, of the Doucin (Malling No. II) Group, but comparing unfavourably with it in early cropping.

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# THE INFLUENCE OF ROOTSTOCKS ON THE BLOSSOMING OF SEEDLING APPLES.

## A PROGRESS REPORT.

By H. M. TYDEMAN.

It has long been a recognised fact among those engaged upon the raising of new varieties of the tree fruits that a considerable period must intervene between the germination of the seed and the ultimate production of blossom and fruit upon the seedling. During this, so called " juvenile stage " which is usually from six to ten years' duration, the seedlings show no inclination to come into fruiting and are often characterised by a thin whippy or spiny type of growth, frequently stunted in character, while the leaves developed around the terminal buds of short spur-like growths remain small and the buds fail to develop into fruit buds. Even where the seedling is worked upon a dwarfing and precocious rootstock this juvenile stage still manifests itself, and such trees invariably take a much longer period to come to blossoming than where ordinary commercial varieties are used upon such stocks. Indeed there is little evidence that this period can be appreciably shortened by any method so far attempted. Bunyard (1) reports upon a system practised by M. Tourasse of Pau recorded in the Revue Horticole 1877, who by systematically shortening the larger roots of seedling apples and pears was able to produce fruits at the age of three or four years. Spinks (2) as a result of his work on apple seedlings concludes that " any treatment which restricts growth, such as ringing, root-pruning, working on dwarfing stocks and growing in pots does not induce earlier fruiting in very young seedlings. On the contrary it tends to keep the trees longer in a " juvenile " state and so delays fruiting." In any case, this delay in fruit production acts as a serious hindrance to the breeder who has not the convenience for the retention over long periods of large numbers of seedlings, many of which cannot fail to prove worthless in the outcome, and to the geneticist anxious to facilitate the production of F2 and subsequent families.

With the object of obtaining information upon the behaviour of seedling apples when worked upon rootstocks of widely divergent character with reference to their influence upon the scion, a considerable number of seedlings so worked have been raised at this Station and have been under observation for some

years. Early indications of differences in the time at which they have come into blossoming are here presented. These seedlings were bred by Mr. M. B. Crane at the John Innes Horticultural Institution, Merton, in the years 1919 and 1920, and consisted of the following families :—

Rev. W. Wilks selfed (seed germinated March, 1920).
Bismark selfed (seed germinated March, 1920).
Cox's Orange × Sturmer Pippin (seed germinated March, 1921).
Sturmer Pippin × Cox's Orange (seed germinated March, 1921).

Buds taken from seedlings of these families were sent to East Malling in 1921 and in the August of that year several buds of each individual were placed upon two of the following rootstocks :—

Either Malling No. VIII, True French Paradise, a weak growing and precocious rootstock ; or Malling No. IX ; Jaune de Metz, a dwarfing rootstock causing extremely early cropping ; and, either Malling No. X, an unnamed stock of German origin, giving rise to a semi-vigorous type of growth in the scions, which come into cropping moderately slowly ; or, Malling No. XIII, also an unnamed stock of German origin ; it is more vigorous and later coming into cropping than No. X.

The original seedlings from which the buds were taken remained at Merton, and from two years old have been treated as cordons. The budded trees at East Malling were lifted as maidens in the early spring of 1923, weighed, and the trees of each individual were divided into two groups as nearly as possible similar as regards weight, and replanted, one group as cordons and the other as bush trees, the latter being cut back to form an 18 inch leg and defeathered. The individual seedlings worked upon dwarfing and vigorous rootstocks were alternated in the rows in such manner that the two contrasted rootstocks bearing the same individual were as far as possible in juxtaposition. Subsequent treatment of the cordons consisted in shortening the laterals to three or four buds, both at planting in 1923, in 1925, and again during the present spring. The bush trees were pruned in 1925, three quarters of the growth being removed, but not again. These bush trees were lifted, examined and weighed during January, 1928, and a large number were discarded, having in the majority of cases made weak stunted growth. The remainder were replanted in the same relative positions as they occupied prior to removal, but not upon the same plot.

In Table I. are shown in summarised form the average weights of the maiden trees at the time of planting out and also, in the case of the bushes, the weight at the time when they were lifted, examined and replanted in January, 1928. It may be readily seen that, although the number of individuals in each combination is not large there is a striking difference in weight, at the maiden

stage, between the trees on vigorous and those on dwarfing rootstocks. Even at five years old the bush trees upon vigorous rootstocks were still in all cases the heavier.

TABLE I.

*Showing average weights of trees as Maidens and at the replanting of the bush trees.*

| | | Cordons and bushes. | | Bushes. | |
|---|---|---|---|---|---|
| | Root Stock. | No. of Trees. | Weight of Maidens (Avge.) ozs. | No. of Trees. | Weight at re-planting 1928 (Avge) ozs. |
| Rev. W. Wilks Selfed | IX. | 5 | 4·0 | 2 | 32 |
| on Nos. IX. and X. | X. | 5 | 5·2 | 2 | 70 |
| Rev. W. Wilks Selfed | VIII. | 9 | 3·3 | 3 | 51 |
| on Nos. VIII. and X. | X. | 9 | 5·2 | 3 | 97 |
| Bismark Selfed | IX. | 4 | 4·5 | 2 | 56 |
| on Nos. IX. and X. | X. | 4 | 8·5 | 2 | 59 |
| Cox X Sturmer | VIII. | 6 | 4·2 | 2 | 50 |
| on Nos. VIII. and X. | X. | 6 | 7·2 | 2 | 60 |
| Cox X Sturmer | VIII. | 2 | 5·7 | 1 | 37·5 |
| on Nos. VIII. and XIII. | XIII. | 2 | 8·5 | 1 | 68 |
| Sturmer X Cox | VIII. | 10 | 4·5 | 4 | 53 |
| on Nos. VIII. and XIII. | XIII. | 10 | 7·3 | 4 | 64 |

In 1925 a few trusses of blossom were recorded upon two cordon trees of the family Bismark selfed, both upon No. IX stock, but it was not until the present year (1928) that any further blossoming was recorded. It was noticeable in the case of the bush trees that the check received owing to the replanting in January, 1928, had caused many of them to be considerably later in coming into leaf than the cordon trees, which had been undisturbed. In eight cases bush trees were still quite dormant at the time of writing (13th June, 1928) and have been excluded. Four of these trees were upon stock No. VIII, two upon No. IX, one upon No. X, and one upon No. XIII, so that there appears to be no definite stock influence here, nor are the trees confined to any particular family, and their exclusion does not affect the significance of the results presented. In Table II. the blossoming records of the trees are tabulated. Only in the cases where trees of an individual upon both dwarfing and vigorous rootstocks are present have the figures been included in the table.

TABLE II.

*Showing number of blossom trusses recorded during the Spring of* 1928.

| Parents. | Root Stock. | Cordons. | | | Bushes. | | |
|---|---|---|---|---|---|---|---|
| | | Total No. of Trees. | No. of Trees which Blossomed. | No. of Blossom Trusses. | Total No. of Trees. | No. of Trees which Blossomed. | No. of Blossom Trusses. |
| Rev. W. Wilks Selfed | IX. | 3 | 2 | 17 | 2 | 1 | 1 |
| on Nos. IX. and X. | X. | 3 | 0 | 0 | 2 | 0 | 0 |
| Rev. W. Wilks Selfed | VIII. | 6 | 1 | 10 | 3 | 2 | 8 |
| on Nos. VIII. and X. | X. | 6 | 1 | 2 | 3 | 1 | 2 |
| Bismark Selfed | IX. | 2 | 0 | 0 | — | — | — |
| on Nos. IX. and X. | X. | 2 | 0 | 0 | — | — | — |
| Cox X Sturmer | VIII. | 4 | 1 | 20 | 2 | 1 | 2 |
| on Nos. VIII. and X. | X. | 4 | 0 | 0 | 2 | 0 | 0 |
| Cox X Sturmer | VIII. | 1 | 1 | 14 | 1 | 1 | 4 |
| on Nos. VIII. and XIII. | XIII. | 1 | 0 | 0 | 1 | 0 | 0 |
| Sturmer X Cox | VIII. | 6 | 5 | 55 | 4 | 2 | 6 |
| on Nos. VIII. and XIII. | XIII. | 6 | 1 | 7 | 4 | 0 | 0 |
| Totals .. .. .. | | 44 | 12 | 125 | 24 | 8 | 23 |

There are ten trees which have not been included in the above table owing to one member of the pair having been missing from the original experiment or having died subsequently. Of these, five have blossomed during 1928, four are upon No. VIII and the remaining one upon No. IX ; and five have not blossomed, two being upon No. XIII and three upon No. X. Through the kindness of Mr. M. B. Crane, of Merton, we are able to add the following information with reference to the blossoming of the original seedlings from which the buds were taken for the material here, and which are growing at Merton.

Rev. W. Wilks selfed. None of the seedlings have blossomed.

Bismark selfed. None of the seedlings have blossomed.

Cox × Sturmer. Six of the seedlings have flowered of which, however, only one is growing here. This individual (included in Table II.) has borne blossom on Stock No. VIII but not on No. XIII.

Sturmer × Cox. None of the seedlings have blossomed.

It may be added that both at Merton and East Malling the majority of the blossoms have given rise to fruitlets but it is perhaps questionable whether many of them will mature.

In commenting upon the results here presented it may be well to emphasise the tentative nature of the conclusions which may be drawn from the data. Only small units of trees have been available for comparison and the units were not repeated in any way. Nevertheless the figures do show quite striking evidence of the earlier blossoming of the trees on the more precocious rootstocks, Nos. VIII and IX when compared with the individuals of the same families upon the vigorous stocks, Nos. X and XIII. Thus of the thirty-four trees upon dwarfing stocks, seventeen have borne in the aggregate 137 trusses of blossom, averaging eight blossom trusses per tree which flowered. Of the thirty-four trees comprising the same individual seedlings upon the vigorous rootstocks Nos. X and XIII, three have blossomed, bearing only eleven trusses, or 3.6 trusses per tree which blossomed.

## Summary.

Preliminary trials as to the possible effect of dwarfing and vigorous rootstocks in shortening the "juvenile period" of apple seedlings have been carried out. The data indicates not only the dwarfing effect obtained by the use of certain rootstocks but an undoubted influence of the latter upon blossoming. Thus exactly fifty per cent. of the trees upon dwarfing and precocious rootstocks blossomed in their sixth year; of trees comprising the same individual seedlings worked upon vigorous rootstocks less than nine per cent. blossomed, whilst only one of the parent plants growing upon their own roots has blossomed.

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(2) *Spinks, G. T.*—"The Treatment of Seedling Apple Trees to Induce Early Fruiting." Journal of Pomology, Vol. IV, p. 141.

# A NOTE ON THE ORIENTATION OF MAIN BRANCHES AND ITS RELATION TO STOCK IN SOME "DOUBLE-STOCK" APPLE TREES.

By R. C. KNIGHT.

A CONSIDERABLE amount of work has been done indicating the individuality and relative isolation of portions of a tree. Harvey (2. pp. 30-31) discussed the pronounced individuality shown by apple spurs, which for assimilation products are largely dependent on leaves borne immediately upon them. Such circumstances make it evident that interchange of materials from any one portion of the plant to another, does not take place freely.

Knowlton (6) found that nitrate applied to the soil on one side of a tree very rapidly found its way into the buds above on that side, and was not evenly distributed on all sides of the head. This indicates that upward translocation takes place vertically and that lateral movement is restricted.

Auchter (1) found that when nitrate was applied to the soil on one side only of the tree, the leaves on that side showed an increased nitrogen content, whilst those on the non-nitrated side lost nitrogen. Similarly, after removal of roots from one side of the plant nitrogen did not reach the leaves above by way of roots on the opposite side. Similar results were obtained with apple, peach and oak, and the evidence indicates that there is normally very little lateral translocation, but that the materials passing up one side of a main stem tend to reach only those organs situated on that side.

At the conclusion of some preliminary experiments on the influence of stock upon scion (4) some trees of Lane's Prince Albert were lifted in which two vegetatively raised stocks of known character had been incorporated with one scion into a single tree. Advantage was taken of the opportunity, although only a small number of trees was available, to make observations upon the disposition of the main branches around the trunk, and the relation between branch-orientation and the different stocks at the base. The general form of the trees is shown in diagram 1, and it was thought possible that in the absence of free lateral translocation, the branches originating on the left hand and right hand sides of the trunk of such a tree might correspond in vigour to the stocks at A and B respectively.

The branches were therefore detached close to the main stem and were weighed, and at the same time records were taken of the position of each branch in relation to the rootstocks, and of the diameter of the stem of each of the latter. In this way it was possible to determine the total weight of branches emerging on that half of the main stem above each root stock. When a branch arose in a

vertical plane exactly at right angles to that containing the two stocks, its weight was divided equally between the two sections. Twenty-eight trees, from 4 to 6 years old, were involved, falling into series according to the nature of the two stocks involved. Table I indicates the pairing of the stocks and the distribution of the main branches in positional relation to each stock.

TABLE I.

*Averages of Stock Diameter and Weight of Branches above.*

| Series. | Stocks. | Smaller Stock. | | | Larger Stock. | | |
|---|---|---|---|---|---|---|---|
| | | No. | Av. Diam. | Weight of Branches on the same side. | No. | Av. Diam. | Weight of Branches on the same side. |
| | | | mm. | gms. | | mm. | gms. |
| 1 | I. and IX. | IX. | 14.0 | 94 | I. | 23.1 | 121 |
| 2 | II. and IX. | IX. | 11.1 | 92 | II. | 23.5 | 133 |
| 3 | I. and I. | I. | 16.4 | 78 | I. | 21.0 | 84 |
| 4 | IX. and IX. | IX. | 13.7 | 42 | IX. | 16.4 | 56 |

Stock No. I is normally more vigorous than No. II which in turn is markedly more vigorous than the very dwarfing No. IX.

These average figures show that in every combination the greater weight of branches is found emerging from that side of the trunk below which is the stronger stock. The differences, however, are smaller than those which have been obtained with trees in which Lane's Prince Albert is united with single stocks of the same varieties as those recorded above.

For example, Lane's Prince Albert on a single No. I stock in six years produced twice (and in a second series of trees three times) as much stem growth as the same variety on IX (3).

Comparative figures for Lane's Prince Albert on Nos. I, II and IX are given in Table II together with corresponding figures for the double stock trees.

TABLE II.

*Stem Growth of Lane's Prince Albert Associated with Different Stocks Values expressed as Percentage of Growth on IX.*

| | Series. | I. | II. | IX. |
|---|---|---|---|---|
| Single Stock Trees .. .. .. | 1 | 339 | 233 | 100 |
| ,, ,, ,, .. .. .. | 2 | 212 | 155 | 100 |
| Double Stock Trees .. .. .. | 1 | 129 | — | 100 |
| ,, ,, ,, .. .. .. | 2 | — | 145 | 100 |

This suggests that although the growth of the branches is to some extent correlated with the nature of the stock immediately below them, the two sides of the tree cannot be regarded as isolated from each other.

A study of the records of individual trees, from which Table I. was compiled supplies further evidence of this. Although the *averages* show that the greater weight of the branches emerged on the side of the stronger stock, yet in 9 out of 28 individual cases, the reverse was the case. Thus, some other factor was involved in determining the relative development of the two sides of the head of the tree. This factor was undoubtedly the position of the uppermost branch, which normally tends to produce more growth than its neighbours, and the position of this branch was the dominant factor in determining the distribution of total branch weight.

In 12 cases in which the uppermost branch was on the same side of the tree as stronger stock, the average of the weight of all branches on that side amounted to 75% of the total branch weight, whilst in 11 cases in which the uppermost branch was associated with the weaker stock the average figure was 64%.

Considering the trees individually it is seen that in 22 of these 23 cases the side which included the uppermost branch also contained the greatest total branch weight.

These figures leave no doubt as to the importance of this top branch in this relation, although the difference between the figures 75% and 64% indicate that a less pronounced influence was exerted by the stocks.

Further evidence of the influence upon the stem growth of factors other than stock proximity is obtained from the figures of distribution of branches over four quadrants (instead of two semi-circles). Diagram 2 shows this distribution in relation to the position of the stocks, and in three cases out of four, one of the quadrants not directly over either stock contains considerably the greatest weight of branches.

Here again, however, in every case, the quadrant directly above the stronger stock contains on the average a slightly greater weight of branches than the diametrically opposite sector, although individual trees show considerable deviation.

There is no doubt that the orientation of the uppermost branch, which was determined largely by chance at the time of pruning the trees as maidens, plays a considerable part in producing the irregular results obtained.

Some observations have already been recorded on the close relation between shoot growth and the thickening of old stems in the apple (5). From this work it appears that when in double stock trees including two stocks of different varieties and vigour, the branches immediately above the weaker stock are considerably larger than those on the other side, it is inevitable that there is somewhere below a corresponding increase in stem diameter. This emphatically

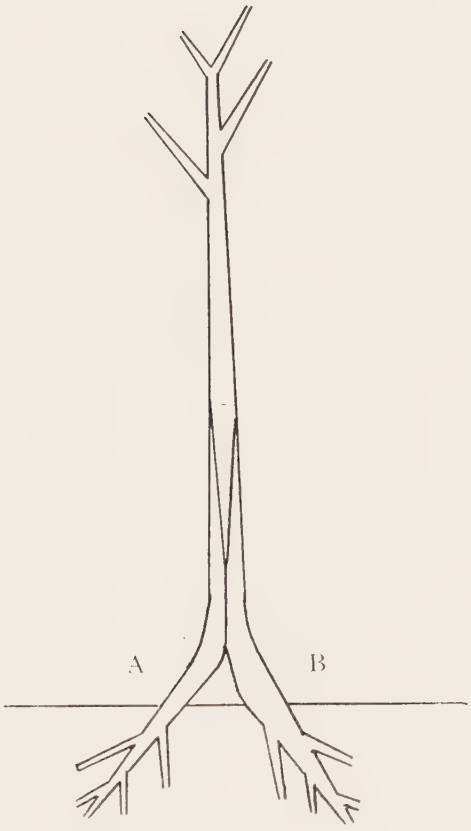
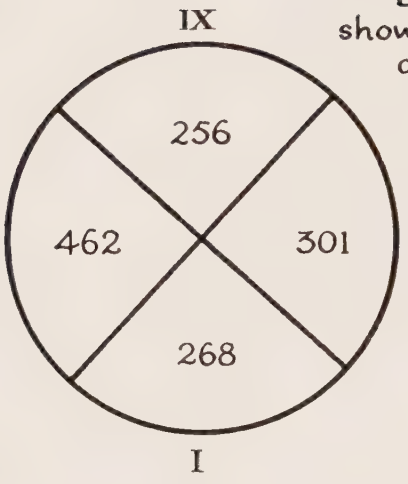
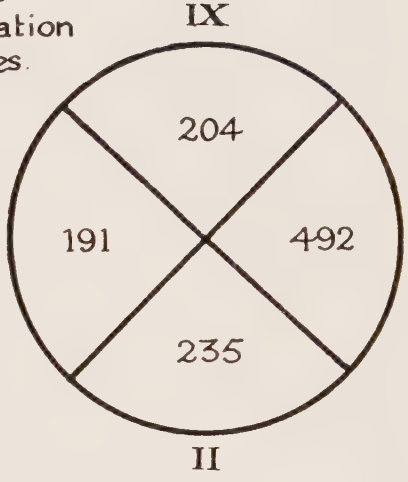


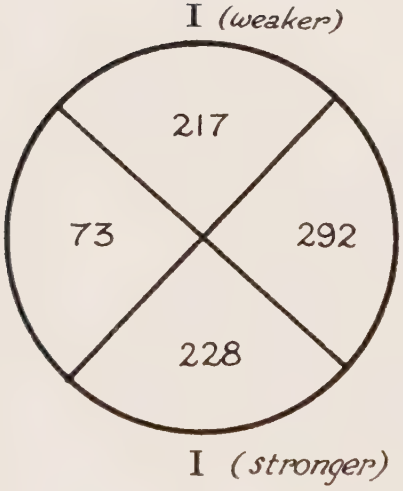

DIAGRAM 1.

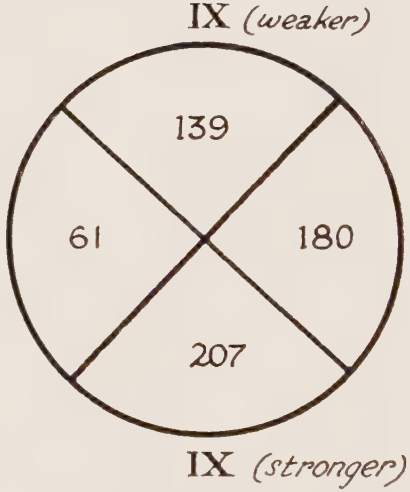
Showing form of trees examined.

Diagram 2
showing orientation
of branches.



does not appear entirely on the dwarfing stock, the stem of which, even in the most extreme case, is considerably smaller than that of the companion vigorous stock. The conclusion is unavoidable that considerable lateral intercommunication has taken place.

One further point was investigated in the course of these observations. It was thought that the position on the original graft, relative to the rootstock, of the bud which produced the main stem, might influence the size of the tree. The results show that of the ten cases in which this bud was in, or within an angle of 45 degrees from, the vertical plane of the weaker stock, six trees were above the average weight for their series and four were below it. On the other hand, of eight trees in which the " maiden bud " was on the same side of the tree as the stronger stock, three were above and five below the average weight and there is thus no apparent correlation between these two factors.

In this small series of trees, therefore, although total vigour is controlled by the combination of stocks employed (4), the main factor in determining the relative vigour of branches on different sides of the main stem is the orientation of the topmost branch, the orientation of the stocks relative to the branches being of secondary importance.

This result is of interest in that it sheds light on the relation of the size of branches to the roots immediately below them.


## Summary.

In a series of trees, each of which was grafted on two stocks (one on each side of the scion) of different vigour, the largest branches were not necessarily those on the side of the strongest root-stock, but those emerging from the highest points on the main stem.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# THE VEGETATIVE PROPAGATION OF WALNUTS.

By A. W. WITT.

The value of standardising Walnut varieties through vegetative methods of propagation has already been stressed by Spence (1, 2) and Taylor (3). It is well known that trees raised from nuts vary widely in the quantity and quality of their ultimate produce, and that there are abroad superior named varieties which are propagated by budding and grafting. Finally, in view of the fact that many of these foreign varieties are likely not to be hardy under English climatic conditions, the Ministry of Agriculture has assisted in a survey of native seedling nuts in the hope of discovering hardy specimens of value. The work is still proceeding along these lines, and further information about profitable local varieties is invited, but the whole investigation presupposes the possibility of easy vegetative reproduction in this country.

In view of the investigations into methods of vegetative propagation already well developed at East Malling, this Station has co-operated in the work, and serves as the nursery for the Walnut selections.

The problem which presents itself is twofold:—

1. The most practical methods of standardising the variety by budding or grafting, for this country, selected scions on to root-stocks, in preference to the raising of seedling varieties.

2. The possibility of standardising the root-stocks themselves—by propagating them vegetatively also and so ensuring, as in other investigations (4), a uniformity of performance for any given scion variety worked thereon.

1. Since walnut trees are raised both in this country, and in certain other European countries, almost exclusively from seed, it may be suspected that budding and grafting methods in the open, such as those used for apples and pears, are not universally successful, though in most Californian and French nurseries grafted trees are the rule, and Knight (5) and Lindley (6) have left directions for so doing. Such methods have indeed now been tried on a field scale for three seasons at East Malling. Though, in the case of grafting in the open, some forty-one trees have actually been propagated, this is a very small proportion of the total number attempted—approximately 150.

To some extent, the failure in this country may be due to the difficulty of obtaining, after sunless seasons, really good, well ripened, graft wood with a comparatively small pith area. French propagators appear to experience the same trouble, since they say that after a hot summer their grafts "take"

well, and after a wet season they are very poor. But, so far, the improvement of the scion wood used here has not resulted in a markedly increased success in the field. It would appear that the main source of trouble is the action of weather. Periods of severe frosts and cold winds almost invariably occur after the grafting season, and, even after some degree of union has apparently taken place, the violent climatic fluctuations seem to prevent the completion of the process of union in many cases. Attempts to circumvent this by delaying the grafting season have failed owing to the increased tendency to drying out.

In the field, the double tongued graft has been used, and, as adopted by Treyves, the grafts have been applied as near to the *root* system as is possible. This is effected by taking away the earth around the plant.

In the hope of decreasing transpiration, and thus preventing drying out, the grafts have been enclosed in waxed paper bags perforated with small holes.

Of the grafts which have survived, eighteen are of four J. *nigra* varieties, and twenty-three are of ten varieties of J. *regia*, the former being apparently less susceptible to frost injury in the early years. It is, however, doubtful whether the Black Walnut would be much planted in this country for its nuts.

Various methods of budding have also been tried in the open. Shield budding has proved a complete failure, and patch and ring budding only slightly more successful, for here again the late spring frosts seem to cause great havoc.

Whilst experiments are being continued in outdoor methods of budding and grafting, in view of the large part evidently played by external conditions, propagation work was initiated indoors under controlled conditions. At least one very successful French grower propagates all his walnuts under glass commercially, since he finds outdoor propagation too uncertain to be profitable. The methods employed at East Malling have been twofold.

(*a*) *Hard wood grafting*. Here, one year old seedling rootstocks are lifted in January from the open ground, where they were raised, and put into $4\frac{1}{2}$ in. pots. They are brought into the greenhouse whilst still quite dormant, in early February, and, in about a fortnight's time, they are grafted. A double tongued whip graft has been used. The *whole* of the scion and the exposed part of the stock are covered with melted paraffin wax.

The grafted plants can be left on the open bench of the house, an average temperature of 60° to 65° F. being maintained, and provided the scion wood has been satisfactory, from 70 to 85 per cent. success is usual.

If the grafted plants are placed in a closed frame with bottom heat—approximately 70° to 75° F.—a union is effected more rapidly.

In comparatively little space, walnut trees can be raised on a commercial scale by these methods, if required.

(*b*) *Herbaceous or Green Wood Grafting.* This method has been used with 75 per cent. success, in July and August.

It has the advantage that when scion wood is scarce very small pieces, even of less than $\frac{1}{4}$ in. thickness, may be used. Further, at this season, propagation-house space is usually readily available, and moreover, the union is rapidly effected. Plants propagated thus rarely make any considerable amount of extension growth in the season of grafting, but in the following spring very vigorous shoots develop.

It may be worth noting that in cases where early indication of fruiting quality has been required it has been found possible to use a scion carrying a flower bud, from which, by hand pollination, fruit has been obtained in the season following grafting.

The method used is as follows :—

The stocks have been planted in January in $4\frac{1}{2}$ in. pots, which method means that the upper portion of the root system is left exposed, above the soil.

For scions, shoots are taken when the wood is about half ripe, i.e., just beginning to become hard, and the pith area has passed the very watery stage.

The scions may be either the terminal portion of the shoot or pieces with one or two eyes, with leaves attached. About half of each leaf is cut away.

When grafting, the woody stem of the stock is almost entirely removed in order that the scion may be inserted as low as possible on the main axis, immediately above the origin of the main roots.

The stock is split in the middle, and a thin slice of bark is pared from one or both sides, as for strap-grafting.

The scion has a strip of bark cut upwards from the base, for about one inch, on one or both sides, and the scion wood is cut as a wedge which is fitted into the stock, while the strip or strips of scion bark coincide with the pared side of the stock. The whole is then tied firmly, and the cut parts paraffin waxed.

The grafted plants are placed in a closed, moderately moist frame (artificial heat is not essential) for from ten to fourteen days, when a union should be effected.

2. The standardisation of the rootstocks presents yet another problem. It is obvious that the seedling rootstocks show considerable variation, and therefore rootstock influence is not improbable. Hence the vegetative propagation of stocks is necessary if a more precise knowledge is to be obtained. Walnuts, however, do not appear to send up suckers from their roots naturally ; layering methods are not readily adaptable ; and, though it has been possible occasionally to get a graft to take upon a piece-root, no success at all has yet been obtained at East Malling in attempts to make root cuttings grow.

Fig. a.

Fig. b.

Walnut Grafting.—a. shows, *on left*, method of herbaceous grafting performed July 2nd, 1928. *On right*, normal dormant scion grafting. March 12th, 1928.

b.—Similar plants photographed August 16th, 1928.

At present the only successful method of propagating these stocks vegetatively has been by soft or green wood cuttings. Several selected parent plants of *J. regia*, and other species and hybrids, have been grown in pots for the purpose. In February they are brought into a greenhouse with an approximate temperature of 60—65°F.

When the new green shoots are well advanced, cuttings with a stem length of 3 to 4 inches are taken. These are cut quarter of an inch below a node and inserted singly in small pots filled with sandy compost.*

If the leaves are not unduly large, they are retained entire on the cutting, otherwise half of each leaf is removed.

The pots containing the cuttings are then plunged in cocoanut fibre refuse, in a closed frame, with bottom heat of approximately 70° to 75° F., the top heat being 65° to 70° F.

The cuttings must be maintained turgid by moderate moisture in the frame. Shading is necessary during bright sunshine, The time taken to produce roots varies with different selections, and ranges from six weeks upwards.

The variety received here, as a seedling "Royal" hybrid (J. *nigra* × J. *californica*) has proved one of the quickest to produce roots.

This method cannot yet be claimed as a commercial success, but sufficient cuttings have been successfully rooted of different varieties and species to suggest that some are distinctly more ready rooting than others, and that clone races might be built up in this way. Varieties of *J. regia* are at present the most promising, although J. *regia* var. *fertilis* is an exception.

Other species, such as J. *nigra*, have proved very difficult, though the application of etiolation methods suggest that even here it may be possible to raise these species in this way.

Investigations are still proceeding along these lines, and any information with regard to the rooting of different varieties, and as to methods of inducing rooting, would prove most valuable at this stage.

The writer wishes to thank Mr. Howard Spence for reading the proofs of this article and making helpful suggestions.

## Summary.

The budding and grafting of Walnuts in the open appears to be frequently a failure as a result of climatic conditions in England.

* The mixture used most successfully has consisted of three-fourths chopped fresh sphagnum moss and one-fourth clean sand, pressed tightly into the pot with the cuttings placed at the side.

Successful methods of hard wood grafting in March and of herbaceous grafting in July and August under controlled temperature conditions are detailed.

Attempts to raise rootstocks by soft wood cuttings are described.

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# A PROGRESS REPORT ON WINTER PRUNING EXPERIMENTS WITH PEAR TREES.

By J. AMOS.

In a report on Winter Pruning Experiments with Apples (1), it was shown that study of the habit of growth and fruiting was of prime importance before adopting any particular method of treatment.

It also revealed the fact that certain treatments, such as leader tipping, always produce the same response, irrespective of variety, whilst other treatments, such as spur pruning, gave widely different results.

With the idea of seeing how far such principles applied to Pears, twelve varieties were planted out in the spring of 1923. Each variety was worked on a known Quince root stock and all were raised in the Station's nursery.

It was thus possible to select uniform batches of trees for the trial.

All the varieties were planted as maidens and shortened to two feet at planting. The resulting new growth was again cut back hard, i.e., to two to four inches from the base the following year, the stronger varieties being less severely treated than the weaker ones.

Thus, up to the end of three years from the bud, all the trees of any one variety were similarly treated, the differential prunings beginning on the third year's growth. Thus, in the spring of 1925 the following scheme of treatments was adopted.

Series (*a*), Regulated.

No tipping of the leader or main extension branches; no spur pruning of lateral shoots; trees only lightly thinned, i.e., badly crossing branches entirely removed. This "Regulated" series was intended for the purpose of studying natural habit.

Series (*b*), Modified Leader.

All leading growths tipped annually. The centre of the tree is kept filled by encouraging the growth of a central leader which is always pruned more lightly than the surrounding ones. The idea is to build up a more or less pyramidal shaped tree, furnished with tiers of fruiting branches. All lateral growths not required for branches (with the exception of those up to 15 cms., which are left), are long spurred, i.e., cut back to three well developed buds, which in practice involves pruning to between two and four inches.

Series (*c*), Open Centre.

The leaders are tipped as in Series (*b*) but the lateral growths are cut hard to one prominent bud. The centre of the tree is kept open or bowl shaped.

This method is a common one with many growers who aim at producing large fruits.

SERIES (*d*)

Are in the early years being treated similarly to Series (*c*). Later, differentiated treatments will be given to the leader growths of these two series. At present this series need not be considered further. The three illustrations of Fertility, at five years old, show well the Regulated, Modified Leader and Open Centre treatments after two years application.

The tipping of the leader growths has varied according to the strength of the variety, the exact amount removed being decided on annually for each variety separately. Approximately, the strong growing varieties have been tipped one third, medium growers one-half, and the weaker growers two-thirds. In this respect the varieties in the experiment have been roughly grouped, according to their vigour under our conditions, as follows:

| Strong Growing Varieties. | Medium Growers | Weak Growers. |
|---|---|---|
| Pitmaston Duchess (32) | Conference (16)* | Chaumontel (16) |
| Beurre d'Amanlis (16) | Fertility (32) | Fondante de Thirriott (16) |
| | Durondeau (32) | Beurre Alexandre Lucas (16) |
| | Emile d'Heyst (32) | Reine des Poires (10) |
| | Hessle (32) | |
| | Georges Bouchier (16) | |

* The figures in brackets refer to the number of trees of each variety planted. Where thirty-two trees were available, eight trees comprise the unit for each treatment; where a lesser number were available, the trees were divided into two equal sets and subjected to treatments (a) and (c) only.

All the varieties were planted between half standard plums, and were not intermixed in the rows, but in each case the adjacent rows on either side are of a different variety, thus allowing as far as possible for inter-pollination. The treatments are alternated in the row, tree one being subjected to treatment (*a*), tree two to treatment (*b*) and so on.

Only three seasons have passed since the differential treatment began and sufficient time has not elapsed to make possible any final conclusions. There are, however, already certain outstanding results from the different treatments, both with reference to general principles of pruning and to special varietal characteristics, which appear worth chronicling at this early stage. As the trees mature and come into full bearing, many of these points will no doubt be modified or even reversed. So far the effects of the differential treatments have been marked on all varieties both on growth and blossom production.

(1) EFFECT ON GROWTH AND HABIT.

In studying the effect upon growth, two sets of records have been taken annually, the total length of new wood shoots, and the girth of the main stem.

With regard to total length of new wood growth, this was definitely less

(a) Regulated, i.e., showing natural habit.

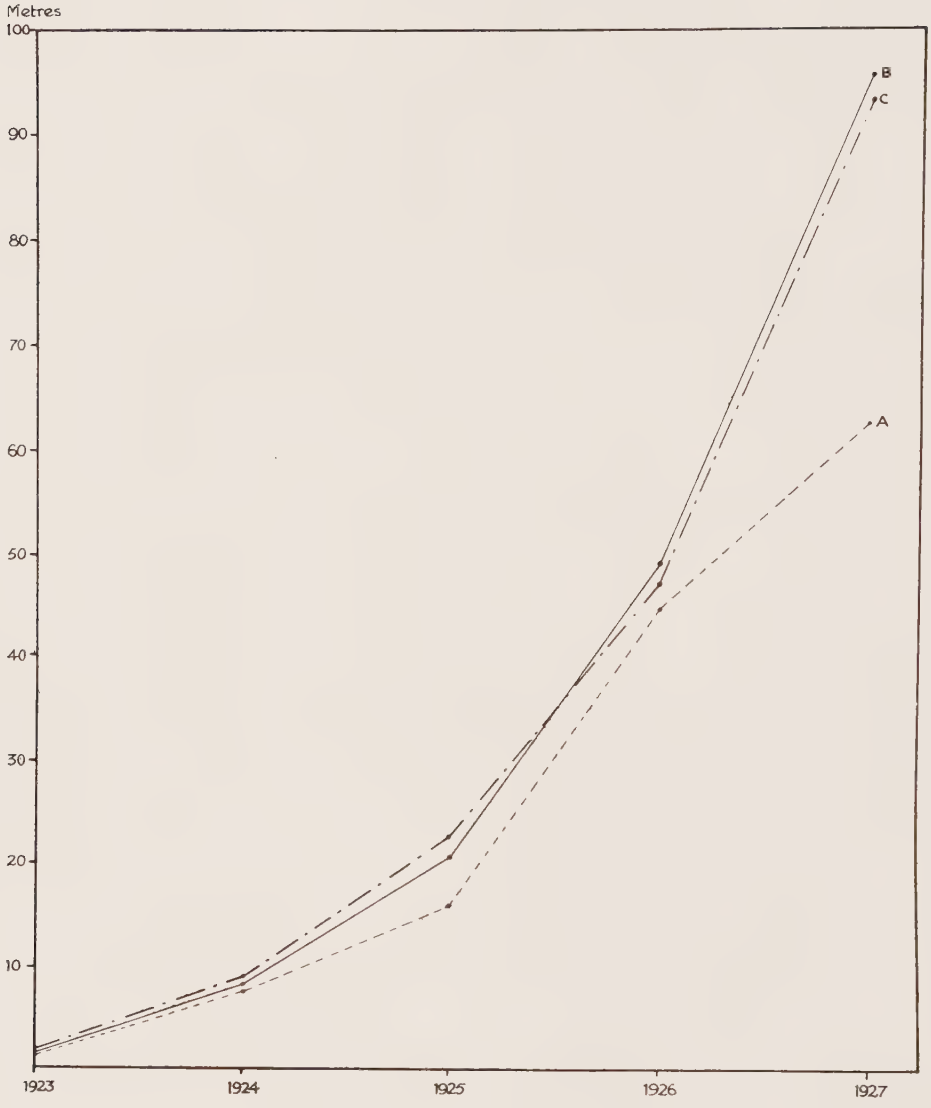
(b) Modified Leader, long spurred.

FERTILITY—FIVE YEARS OLD.

(c and d) Open centre, short spurred.

PITMASTON DUCHESS.

Total new wood growth from year to year.




A.—Regulated series—Leaders unpruned.
B.—Modified Leader—tipped and spurred.
C.—Open centre—tipped and spurred.

in the untipped trees the first year after being left unpruned. In the second season, the length of new wood was almost identical on both the untipped and pruned trees. The untipped however again fall far behind in the third season. All the varieties have, without exception followed this general rule. A graph illustrating this point is shown opposite.

In the majority of cases, the average length of new growth per shoot was less on the untipped trees, but the actual number of shoots was greater. Since there were several exceptions, it must be concluded that this is a varietal characteristic.

The girth measurements, taken in 1926 and in 1927, are, with two exceptions, greater for the untipped trees. The girths of the tipped trees of Durondeau and Pitmaston Duchess were greater in 1926 than those of the untipped trees, but, like all other varieties the untipped series were well ahead in 1927. The greater length of new annual growth in the tipped trees and the greater girth increment of the untipped trees shows clearly the different distribution of new growth under the two treatments.

TABLE I.

*Girth of Main Stem in mms. at 9 inches above ground level.*

| | 1926 After first treatment. | | | 1927 After second treatment. | | |
|---|---|---|---|---|---|---|
| | a | b | c & d | a | b | c & d |
| Conference | 118 | 83 | — | 156 | 139 | — |
| Durondeau | 101 | 110 | 102 | 141 | 125 | 128 |
| Emile d'Heyst | 122 | 110 | 108 | 157 | 143 | 141 |
| Fertility | 154 | 146 | 136 | 191 | 188 | 169 |
| Hessle | 139 | 131 | 127 | 186 | 172 | 167 |
| Pitmaston Duchess | 129 | 136 | 124 | 177 | 164 | 156 |
| Beurre d'Amanlis | 148 | — | 140 | 192 | — | 179 |
| Beurre Alexandre Lucas | 82 | — | 71 | 114 | — | 95 |
| Chaumontel | 90 | — | 75 | 114 | — | 91 |
| Fondante de Thirriott | 93 | — | 93 | 125 | — | 118 |
| Georges Bouchier | 137 | — | 112 | 177 | — | 141 |

(2) BLOSSOM AND FRUIT PRODUCTION.

It has already been stated that the differential treatments began in the spring of 1925. Even in the year following (1926), the effect, on blossom bud formation, of leaving trees untipped was most strikingly demonstrated. In every variety but one, viz., Chaumontel, the trees so treated carried much blossom. The same result was repeated in 1927 and 1928, but to a still greater degree and even on Chaumontel. On the other hand, the sets of pruned trees, were, with one or two exceptions, almost devoid of blossom the first two years after pruning. In the third season (1928), the number of blossom buds on these showed an increase, but they were still very deficient when compared with the untipped trees.

Table II. gives the average number of blossom buds per tree under each treatment for the three seasons, where recorded. In two cases, namely Durondeau and Fertility, it will be seen that there has been considerable blossom bud from the very beginning under all treatments, yet they prove no exception to the rule, The untipped trees, as the table shows, have fairly large numbers of blossom buds, sufficient at least to have set a crop.

Unfortunately in both seasons, viz., 1926 and 1927, unfavourable conditions prevailed during blossoming, and, in consequence, little fruit has set. In 1927, frost destroyed practically all the blossom, and unfortunately that shown in the column for 1928 has suffered a similar fate.

TABLE III.

*Average number of Fruits per tree 1926 and 1927 together.*

| | Regulated. | Modified Leader. | Open Centre. |
|---|---|---|---|
| | a | b | c & d |
| Conference .. .. .. .. | 1 | 0 | 0 |
| Durondeau .. .. .. .. | 5 | 3 | 1 |
| Emile d'Heyst .. .. .. | 27 | 3 | 1 |
| Fertility .. .. .. .. | 43 | 1 | 0 |
| Hessle .. .. .. .. | 44 | 6 | 2 |
| Beurre d'Amanlis .. .. .. | 1 | 0 | 0 |
| Fondante de Thirriott .. .. | 11 | 0 | 1 |

Table III. shows the average number of fruits per tree for the two years 1926 and 1927 together.

In habit of fruiting, as shown by the type of blossom buds, wide differences have been found in the varieties under trial. Detailed blossom counts and analyses have been made on both the pruned and untipped trees. The records include the blossom both on the prunings removed and also left on the tree, thus giving a complete picture before and after each treatment.

For the purpose of classification, the blossom buds are grouped under three headings :

(1) " Terminals," at the ends of one year shoots, five cms. long or more ; (2) " Axillaries," those formed in the axils of leaves on the previous year's shoot and (3) " Spurs," on shoots less than five cms. long. The spur blossom buds were almost universally from naturally formed spurs. They have not, up to the present, been produced on the spur-pruned laterals.

Table IV. gives the figures for two seasons of the different classes of blossom buds on some of the varieties under trial, together with the totals per tree under each treatment and the number removed at pruning.

TABLE II.

*Average Number of Blossom Buds per Tree.*

| | *1925* Before Differential Treatments. | | | | *1926* After First Treatment. | | | | *1927* After Second Treatment. | | | | After |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | c & d | | | a | c & d | | | a | c & d | | |
| | No. of Trees | Blossom Buds | No. of Trees | Blossom Buds | No. of Trees | Blossom Buds | No. of Trees | Blossom Buds | No. of Trees | Blossom Buds | No. of Trees | Blossom Buds | No. of Trees |
| Conference | *8* | 3 | — | — | *8* | 21 | — | — | *8* | 11 | — | — | *4** |
| Durondeau | *8* | 11 | *16* | 15 | *8* | 118 | *16* | 11 | *8* | 161 | *16* | 80 | *4* |
| Emile d'Heyst | *8* | 0 | *16* | 0 | *8* | 11 | *16* | 1 | *8* | 94 | *16* | 3 | *4* |
| Fertility | *8* | 7 | *16* | 7 | *8* | 56 | *16* | 6 | *4* | 130 | *12* | 25 | *4* |
| Hessle | *8* | 3 | *16* | 5 | *8* | 107 | *16* | 1 | | | — | — | *4* |
| Pitmaston Duchess | *8* | 1 | *8* | 1 | *8* | 46 | *8* | 1 | *4* | 80 | *8* | 6 | *4* |
| Beurre d'Amanlis | *8* | 0 | *8* | 0 | *8* | 32 | *8* | 0 | *8* | 71 | *8* | 1 | *4* |
| Beurre Alexandre Lucas | *8* | 1 | *8* | 3 | *8* | 37 | *8* | 2 | - | | — | | |
| Chaumontel | *8* | 0 | *8* | 0 | *8* | 0 | *8* | 0 | | | | | |
| Fondante de Thirriott | *8* | 0 | *8* | 0 | *8* | 70 | *8* | 0 | — | — | | | |
| Georges Bouchier | *5* | 2 | *5* | 2 | *5* | 30 | *5* | 2 | | - - | | - | |
| Reine des Poires | *4* | 0 | *5* | 0 | *4* | 12 | *5* | 2 | — | — | | | |

a—Regulated Trees. c & d—Leader tipped and spurred (open centre).

The figures for series b, modified leader tipped and spurred, follow closely those for series c & d, and are therefore not given separatel

* Time did not permit a detailed count of more than four regulated trees of each variety.

— = Blossom records not taken.

It will be seen that whilst varieties like Emile d'Heyst and Conference produce mainly spur blossom buds, the varieties Durondeau, Fertility and Hessle, produce, in addition, many " terminal " and " axillary " blossom buds. If the classes of blossom buds are compared under the different treatments, it will be seen that this character remains unaltered and may therefore be concluded to be a varietal characteristic. Being produced principally on the long one year's growths, the terminal " " and " axillary " blossom buds are naturally much reduced in number by pruning. In many varieties the number of " terminal " and " axillary " blossom buds are not materially altered by the treatments, the " spur " blossom buds are however in every case greatly reduced in number in the tipped series. The variety Conference, even in the regulated series, is slow to furnish itself with blossom buds, for it is only after being left unpruned for two seasons that it produces any appreciable number.

TABLE IV.

*Average Number of Blossom Buds per tree in different classes.*

1927 and 1928.

| | | 1927 | | | | | 1928 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Terminal. | Axillary. | Spur. | Total. | Removed in Pruning. | Terminal. | Axillary. | Spur. | Total. | Removed in Pruning. |
| Conference | a | 6 | 1 | 5 | 12 | 0 | 3 | 11 | 224 | 238 | 0 |
| | b | 0 | 0 | 1 | 1 | 0 | 5 | 1 | 18 | 24 | 1 |
| Durondeau | a | 49 | 77 | 35 | 161 | 37 | 38 | 27 | 311 | 376 | 5 |
| | b | 34 | 44 | 4 | 82 | 72 | 33 | 28 | 32 | 93 | 49 |
| | c & d | 33 | 43 | 4 | 80 | 76 | 44 | 68 | 23 | 135 | 110 |
| Emile d'Heyst | a | 2 | 4 | 88 | 94 | 4 | 0 | 0 | 421 | 421 | 2 |
| | b | 1 | 0 | 7 | 8 | 3 | 9 | 0 | 65 | 74 | 2 |
| | c & d | 0 | 0 | 3 | 3 | 0 | 1 | 1 | 62 | 64 | 3 |
| Fertility | a | 40 | 20 | 70 | 130 | 14 | 28 | 31 | 431 | 490 | 10 |
| | b | 26 | 10 | 3 | 39 | 35 | 65 | 40 | 31 | 136 | 80 |
| | c & d | 18 | 7 | 0 | 25 | 25 | 27 | 17 | 13 | 57 | 43 |
| Hessle | a | — | — | — | — | — | 29 | 77 | 465 | 571 | 53 |
| | b | — | — | — | — | — | 53 | 94 | 57 | 204 | 123 |
| | c & d | — | — | — | — | — | 54 | 138 | 19 | 211 | 179 |
| Pitmaston Duchess | a | 22 | 4 | 54 | 80 | 2 | 72 | 35 | 372 | 479 | 11 |
| | b | 7 | 1 | 0 | 8 | 5 | 29 | 4 | 8 | 41 | 14 |
| | c | 4 | 2 | 0 | 6 | 6 | 10 | 2 | 0 | 12 | 12 |
| Beurre l'Amanlis | a | 4 | 3 | 64 | 71 | 1 | 47 | 43 | 319 | 409 | 4 |
| | c | 1 | 0 | 0 | 1 | 0 | 12 | 1 | 59 | 72 | 13 |

a—Regulated series—Leaders unpruned.
b—Modified Leader—tipped and spurred.
c & d—Open centre—tipped and spurred.
-- = Blossom record not taken.

In addition to actual measurements of growth and records of blossoming already discussed, notes have been made as to the general behaviour of the varieties under the different treatments. These will be given briefly.

(*a*) Regulated, i.e., Untipped.

The tendency for most pear varieties is to form a pyramidal shaped tree. This being so, very few unshapely trees have resulted from being left untipped.

The two varieties, Durondeau and Hessle have, however, become somewhat weak and inclined to spread, and they show need of support. Beurre d'Amanlis, although a strong grower, makes long clean growths which are inclined to spread and become very unshapely. Apart from these three, all the other varieties have remained compact and erect.

The regulated trees of Fertility and Georges Bouchier have become much more seriously affected with both Scab and Canker than the tipped trees. The reason for this is described elsewhere by Wormald (2).

(*b*) Modified Leader.

Owing to the natural tendency to pyramidal growth, the leaving and maintaining of a central leader has, in practically all cases, been easily accomplished. In the variety, Emile d'Heyst, the central leader shows a tendency to overpower the lower branches.

Where spur pruning of the laterals has been carried out, blossom buds are now in most cases being formed. The stronger laterals, when spurred, also make new wood growths in addition. Where weaker laterals have been shortened, they have in 1928 made blossom buds only. The leaving of shoots up to 15 cms. long has in all cases increased the number of blossom buds remaining on the tree, and hence the chances of a few early fruits. On Pitmaston Duchess, for instance, practically all the fruit buds up to the present are of this type, and here the shoots have been left somewhat longer than was originally intended. These long "brindilles" will, it is found, in the second year be well furnished with "spur" blossom buds. On Emile d'Heyst such "brindilles" are almost entirely absent, this variety making nothing but spur blossom buds.

(*c*) Open Centre. Leader Tipped, Hard Spurred.

With some varieties of Apples severe leader tipping was found to encourage excessive wood growth. In some cases also the short spurred laterals actually died out. So far, none of the varieties of Pears have shown these tendencies. The leaving of a fair length of leader has no doubt prevented excessive wood growth to a great extent. So far the hard spurring appears to have been effective, for, in the majority of cases, potential blossom buds are being produced.

Even where wood growth is made after spurring, the laterals, on being spurred a second time, show the same tendency to form these potential blossom buds. These trees when compared with the long spurred trees (See Table IV). are seen to fall behind in actual numbers of blossom buds, the numbers on each are so small that it is doubtful if they are significant at this early stage.

At this period of the trial it is not possible to give any recommendations as to particular treatment for the different varieties. It should also be pointed out that although the production of blossom and fruit has been in favour of the unpruned trees one would not at this stage advocate this method for the growing of Pears.

## Summary.

The three seasons winter pruning have shown that :—

1. The total length of new annual wood growth is greater in the tipped trees in the first and third season after treatment. In the second season almost identical amounts are made on both unpruned and tipped trees. The amount per shoot has, in the majority of cases, throughout been greater on the latter.
2. The unpruned trees in all cases show a greater girth measurement after the second treatment.
3. Blossom bud formation in early years is reduced by tipping.
4. The leaving of trees unpruned tends to early fruit production.
5. The production of " terminal " and " axillary " blossom buds is shown to be a varietal characteristic.
6. The tipped trees have been less affected by Scab and Canker than the unpruned trees in certain cases.
7. Hard spurring of the laterals, has resulted, in the majority of cases in the production of potential blossom buds.

## References.

1. *Grubb*, N. H. Winter Pruning Experiments with Apple Trees. Journal of the Royal Horticultural Society, Vol. XLVII., Parts, 2 and 3, p. 139. September, 1923.
2. *Wormald*, H. Canker in Fertility Pears Trees. Journal of the Ministry of Agriculture and Fisheries. Vol. XXXIV. p. 162. May, 1927.

# Section III.

## Mycology and Bacteriology.

# NOTES ON PLANT DISEASES IN 1926.

By H. WORMALD.

## Introduction.

In previous reports it has been shown that the incidence of infectious diseases of cultivated plants is closely correlated with the weather conditions, the amount of moisture in the air being a factor of primary importance in the case of certain plant diseases. The rainfall during the earlier months of 1926 was above the average and associated with this was the unusual prevalence of rots caused by *Botrytis cinerea* and of blossom wilt of cherries caused by *Sclerotinia cinerea*, while Potato Blight appeared even earlier than in 1924.

The cold wet weather at the time the apple trees were coming into flower was doubtless directly responsible for the small apple crop since trees which blossomed well set but little fruit, and no parasite could be found to which the damage to the flowers could be attributed.

Diseases which are due solely to adverse weather conditions cannot generally be obviated. On the other hand certain infectious diseases which, in favourable years produce little noticeable loss, may in other years (when conditions encourage infections by parasites) develop into epidemic outbreaks and care should be taken not to neglect such diseases even in years when they are apparently negligible. One case in point is the blossom wilt of Morello cherries (referred to again on a later page), which was not very conspicuous in 1925 and therefore little or no serious attention was given to it by some growers, with the result that sources of infection, in the form of twigs bearing the fungus, were left on the trees to cause serious loss in 1926 when conditions were particularly favourable for the parasite.

## Injury caused by Disease-control Measures.

Certain types of injury were noted which were caused by the application of substances used for the control of disease. On the Station premature leaf-fall following the application of sulphur-containing washes was a conspicuous feature in the spraying trials. Trees of Cox's Orange Pippin and Stirling Castle sprayed with lime-sulphur, even at a concentration as low as 1 part in 150, lost from 30 to 50 per cent. of the leaves from many of the leading shoots.

A spotting of plums on a farm at Goudhurst was probably a form of lead-arsenate injury. The blackened areas were almost invariably at the lower end of the fruit where drops of the spray fluid accumulated. The injury did not penetrate far into the fruit, but there was considerable disfigurement of the half-grown plums.

Young trees of Cox's Orange Pippin in a nursery suffered from a kind of canker which killed the bark around the nodes where the side shoots had been cut off. Nearly every tree in a plot of 150 had one or more of these cankers. On one tree as many as eleven were counted in a length of fourteen inches, and several trees were quite dead in the upper half. All the cankers smelt strongly of paraffin and this appears to be a case of injury caused by the application of paraffin to cut surfaces ; the treatment was presumably for checking attacks by American Blight, but the true facts of the case could not be ascertained.

### Diseases New to this Country.

Four diseases associated with the presence of fungi which apparently have not previously been recorded for this country came to my notice during the year. These diseases, together with the name of the associated fungus in each case, are listed here, but will be referred to again on the pages mentioned.

A withering of leaves of Kentia palm (*Colletotrichum* sp.). See page 87.
Hawthorn Leaf Blotch (*Sclerotinia crataegi*). See page 86.
Hop Leaf Spot (*Ascochyta* sp.). See page 85.
Dahlia Leaf Spot (*Ascochyta* sp.). See page 86.

Mr. Harris also found a species of *Phoma* associated with a wilting of hop bines ; this too is a disease not previously noted in this country.

### Potato Blight (*Phytophthora infestans*).

In 1926 this disease appeared unusually early, as a result of the very wet spring. At East Malling it was first noticed on June 9th, when it was seen on the leaves and haulms of potatoes which had been left over winter in a small clamp for the purpose of feeding to pigs. The diseased potatoes were promptly destroyed by burning. On June 22nd the blight was appearing on the varieties Eclipse and British Queen on the Station, and also on Eclipse in a private garden at East Malling. Six days later it was seen on the variety King Edward VII. on the Station. As a result of these observations spraying operations commenced before the end of June. On June 29th leaves of King Edward VII. and Great Scot were received from Tonbridge where the disease was said to be prevalent.

### Grey Mould (*Botrytis cinerea*).

The common grey mould fungus *Botrytis cinerea* was prevalent in spring, through the summer, and particularly in September. It was found on a large number of plants under conditions suggesting that the fungus was the direct cause of the injury though the attacks were favoured by the weather conditions. The *Botrytis* species thrive in wet weather and especially in moist ill-aerated situations as when plants are overcrowded. The plants on which I found the grey mould in 1926 are mentioned below and probably many other cultivated

plants served as hosts for this fungus during that year, which was a particularly favourable one for the growth and dissemination of this fungus.

*Morello Cherry Shoots.* A number of flowering spurs of Morello cherries on the trial plot on this Station were killed just before the flowers opened. The injury suggested infection by *Monilia cinerea* except that the latter usually infects through the open flowers. On keeping the diseased flowers in a moist chamber for two days fructifications of *Botrytis cinerea* appeared on them. In one case the brown discoloration had extended from the flowers into the tissues of the shoot ; particles taken from the interior of the shoot were placed on a culture plate and these gave rise to typical cultures of *Botrytis cinerea*, showing that the fungus had actually invaded the shoot.

*Plum Shoots.* A few young shoots of Victoria plum trees on one of the stock trial plots on the Station were killed and bore fructifications of *B. cinerea*.

*On Fruit.* The same fungus was found causing fruit rot of sweet cherries, strawberries and loganberries. A mummified apple found in May in an orchard was found covered with *Botrytis* fructifications ; the apple had apparently been infected the previous season and had remained on the tree through the winter.

*Red Currant Leaf.* A leaf blotch of red currant was seen on the Station ; it showed the usual type of leaf injury caused by *Botrytis*, the blotch being greyish, bordered by a dark line and bearing fructifications of the fungus mostly on the lower side of the blotch.

*Beans and Peas.* On dwarf French beans in a garden at Maidstone it was found attacking plants in a bed of the variety Canadian Wonder. The plants were rather crowded, a condition favouring attacks by Grey Mould. Blotches on the leaves were up to one inch in diameter ; they were greyish in colour, but bordered by a dark line outside which was usually a yellowish zone. Fructifications of *B. cinerea* were present on the under surface of the blotches and occasionally on the upper surface. In many cases it was seen that the rot had started where a flower or a petal had fallen and stuck to the surface of a leaf. Most of the plants in the bed showed leaf infections, but infection of the pods was seen on only two plants.

The fungus was also found associated with a pod rot of runner beans, of " Mangetout " beans and of broad beans.

On garden peas it was observed on the seeds of pods which had been attacked by the larvæ of the Pea Moth.

*Ornamental Plants.* Grey Mould was also found on a number of ornamental plants and shrubs. Leaves and shoots of lilac bushes at Maidstone and Addington were killed, a number of young trees being very badly damaged. The fungus was found on flowers of begonia and dahlia, and typical grey mould leaf blotches were found on dahlia, Japanese anemone, phlox and catalpa. In

the case of these leaf blotches it was found, as mentioned for dwarf beans, that infection often arose where a petal had fallen on a leaf and remained there.

### Brown Rot Diseases of Fruit Trees.*

The brown rot diseases of fruit trees caused by *Sclerotinia cinerea* and *S. fructigena* were unusually prevalent during 1926. The wet spring favoured infection of the flowers by *S. cinerea* and blossom wilts were common in consequence, while in late summer infection of ripening fruit by *S. fructigena* was responsible for considerable loss.

Blossom wilt of cherries (*Sclerotinia cinerea*) was an instance illustrating the effect of weather conditions on the incidence of disease. Early varieties were in flower during a brief fine period which favoured pollination and early setting. A period of dull wet weather with low temperatures then set in, which not only favoured the development of the blossom-wilt fungus, but also produced conditions unfavourable for bees, so that pollination was retarded and since the flowers remained open for a long time they were more liable to infection. Thus in one orchard visited in May the variety Early Rivers, which had been in flower during the sunny period when bees were active, gave promise of a good crop, while others, later varieties such as Kentish Bigarreau (Amber), Florence and Napoleon, were very badly infected with blossom wilt.

Morello cherries particularly suffered in this way for they were in flower for about four weeks during which period they were liable to infection, and in plantations where dead infected wood had not been cut out before the flowers opened the result was disastrous.

Visits were paid in spring to a number of Morello plantations where blossom wilt was prevalent. In one plantation, in the neighbourhood of Maidstone, of about 1,000 trees, every tree (with the exception of two or three very young trees with few flowers) showed blossom wilt and recently killed twigs. An attempt had been made to cut out the dead wood of the previous year's infection, but it had not been thoroughly carried out and most of the trees showed one or more old dead twigs bearing the fungus, and it was observed that most of the wilted trusses of flowers were in close proximity to the fungus-bearing twigs. In another plantation on the same estate the trees had received no attention whatever and no attempt to cut out the dead wood had been made ; on these trees all the blossom trusses were killed by blossom wilt infection (either directly or indirectly by the death of the twigs) and the trees had the appearance of having been swept by fire.

On another farm near Maidstone a plantation of some 200 young Morello trees (five years old) were seriously affected by blossom wilt.

* This section was published in *The Gardener's Chronicle*, September 17th, 1927, under the title "Brown-Rot Diseases of Fruit Trees in 1926," and is reprinted here by permission of the Editor of that journal.

A plantation of five or six hundred Morello trees about fifteen years old in the north-west of the county was also visited. In this case practically all the flowers were withered and many branches were being killed back. I was told that there had been a slight attack of the disease in 1925, but that owing to pressure of other work the necessary cutting out of dead wood had been neglected with the result that this had served as a source of infection for the 1926 crop.

That the very unfavourable weather conditions were important factors in these epidemic outbreaks is undeniable, but a great deal of the infection could have been avoided if the precaution had been taken to remove all the twigs killed the previous year, as shown by the fact that even where the cutting out had been imperfect there was considerably less infection than in those cases where it had been omitted altogether. As the flowering period was so prolonged the flowers which opened early became infected and these soon produced masses of spores which also served as dangerous sources of infection for the flowers which opened later.

Certain varieties of plums were also seriously infected with blossom wilt, and " wither tip " (particularly in Victoria plums) was prevalent.

An instance of wither-tip (infection followed by withering of the young green shoots) was found on a Myrobolan hedge ; no particular harm was caused in this case and its chief interest lies in the fact that such diseased shoots, occurring in unexpected places, are easily overlooked and might serve to infect the more valuable fruit trees.

Wither-tip in cherries is much less common than in plums, but examples were found on young trees on the East Malling Research Station ; during the winter these produced pustules of spores on the dead shoots as in the case of plums. On a plot of " maiden " cherry trees (variety Napoleon) the leading shoots were killed back in this way on about half the trees. Wither-tip was also seen on large established trees in the neighbourhood of East Malling.

A disease of a Japanese flowering cherry (*Prunus serrulata*) killing back the tips of the branches, first observed in 1925 as mentioned in the last Report, was again noted in 1926. Laboratory cultural methods showed that (as before) the mycelium of *Sclerotinia cinerea* was present in the dead twigs, and the inference is that this fungus is the cause of the disease.

An unusual form of disease was found on some Kentish Red cherry trees in the Weald. Certain parts of the branches became unusually swollen ; the bark below these tumorous-looking outgrowths was brown and dead. On placing particles of this diseased bark on cultural plates the fungus *S. cinerea* grew out and the probable explanation of the abnormal condition of the branches is that infection took place through the blossoms ; from the flowers the fungus extended into the bark of the twigs and killed it, while the wood continued to convey sap to the parts beyond the infected area. Infection thus caused a

type of natural "ringing" and there was an accumulation of food material above the injury with hypertrophy of the tissues.

Blossom wilt of apple trees (*Sclerotinia cinerea* f. *mali*) was again serious in places. The Lord Derby variety is particularly susceptible to this disease, and trees of this variety on two farms at East Malling were seen, during the winter of 1926-27, with numerous cankers and dead spurs bearing the fructifications of the fungus.

*Sclerotinia fructigena*, the common brown-rot fungus which infects the fruit of apple and pear trees, was again responsible for much rotting of the fruit. Though usually associated with the "core-fruit" (apple, pear, and quince) it caused much rotting of plums and at East Malling was responsible for more rotting of the plum crop than *S. cinerea*. *S. fructigena* was also found on the fruit of the Cherry Plum (Myrobolan) and of Morello cherries.

The prevalence of *S. fructigena* in late summer made careful picking and sorting a necessity if the fruit was to be marketed or stored. Cases were noted where apples had been picked *from* the stalks instead of *with* the stalks, with the result that the brown rot fungus immediately got in at the wound and there was conspicuous rotting within two or three days after picking, the rot in these cases starting at the stalk end. The variety in which this type of infection was observed was James Grieve, a variety very susceptible to brown rot.

Although *S. fructigena* invariably (so far as is known at present) infects through the fruit, in certain soft-wooded varieties of apples it can extend from the fruit into the spurs and branches and so cause cankers. Specimens of dead spurs of James Grieve received from Essex during the winter bore barren fungal pustules, particles of which when transferred to culture plates gave rise to typical cultures of *S. fructigena*.

A leaf-blotch of hawthorn caused by a fungus closely related to the brown-rot fungi is described on a later page.

Apple and Pear Scab (*Venturia inaequalis* and *V. pirina*).

These diseases were again prevalent and call for no special remarks except that a few cases of infection of the petals were observed on the flowers of the variety Worcester Pearmain on the Station. Scab is frequently found on the calyx and fruitlets as the flowers are setting into fruit, particularly on pears, but I know of no previous record of scab lesions on the petals of a commercial variety, though an instance was noted in the last Report of petal infection in an ornamental species of Pyrus.

On the pear variety Marechal du Cour young scab lesions on the current year's shoots were found as early as June 22nd on specimens received from Faversham.

The Pink Rot fungus (*Cephalothecium roseum*) which often infects stored

apples through scab spots, was seen on the variety Worcester Pearmain on September 8th, very soon after the fruit had been picked.

Pear Canker (*Nectria galligena*).

On the stock trial plot of Fertility pears on the Station the standard trees were found, in spring, to be badly cankered. The cankers were associated with scab lesions and the assumption is that the scab wounds allowed the entrance of the canker fungus which killed back the branches. The bush trees which had been pruned and leader-tipped bore a little scab and few cankers, but the damage caused was negligible compared with that on the standard trees.*

The canker fungus can, of course, infect through wounds other than those caused by scab. One serious case of canker infection after pruning was brought to my notice in November. The trees were thirty years old pear trees which had been headed back and worked with Fertility. They had made vigorous growth but became badly cankered. In every case examined the cankers were on the two year old wood and each canker had at its centre a stub where a lateral branch had been cut off. The pruning had been carried out with a " standard pruner " about the end of January, and infection probably took place very soon afterwards, for when examined in November some of the cankers had completely girdled the branches, which were in consequence quite dead beyond the cankers. In the case of large trees it is practically impossible to paint over such pruning wounds, but the precaution should be taken of cutting out all cankers from the trees before the normal pruning operations commence, or spores may be carried to the pruning wounds and so cause infection.

Specimens showing an " Eye Rot " of Fertility pear, received from near Canterbury, bore a fungus resembling the conidial stage of the canker fungus and recent work† has established the identity of the eye-rot fungus with *Nectria galligena*. A similar eye-rot is sometimes found on apples, particularly on the variety Worcester Pearmain.

Apple Mildew (*Podosphæra leucotricha*).

Mildew was again responsible for a certain amount of damage to the more susceptible varieties of apple. The leaves, shoots and flowers are very frequently mildewed, and occasionally the fungus is found on the fruit. Early in August it was found on a number of young apples of the variety Early Victoria on the Station. Many fruit bodies (*perithecia*) of the fungus, seen as minute black dots, were present on the infected apples.

The same fungus sometimes infects pear trees. One mildewed pear shoot was found on the stock trial plot.

* A more detailed account of this outbreak has been published in the Journal of the Ministry of Agriculture and is reprinted on pages 92-95.

† Weston, W. A. R. Dillon. Notes on the Canker Fungus (*Nectria galligena* Bres.) Trans. Brit. Mycol. Soc., XII, 1927.

Plum Rust (*Puccinia Pruni-spinosæ*).

This disease was unusually prevalent in 1926, the infected leaves on many plum trees (particularly Victorias) turned yellow and fell prematurely. Usually the disease appears rather late in the season, and as it is confined to the leaves does little real damage. One stage of its life-history is passed on anemones, including the wild anemone of the woods and also on cultivated species. Two instances of the disease on *Anemone coronaria* came to my notice during the year, at Addington and at Goudhurst. Diseased anemone plants may be recognised by their more upright leaves which have fewer lobes than the healthy ones. On the underside of infected leaves are seen the cup-like fructifications (" cluster cups ") the spores from which are able to infect plum leaves.

A Wood-rotting Fungus on Plum Trees.

In February specimens of *Fomes pomaceus*, a fungus sometimes found on plum trees, were received from Tonbridge and Canterbury, where it was attacking plum trees, and from East Malling where it was found on a species of *Prunus* in a hedgerow. The growers were anxious to know whether this fungus was the Silver Leaf fungus. *Fomes pomaceus*, though generally considered to be a slow-growing wound parasite, is not nearly so dangerous as *Stereum purpureum*, which causes Silver Leaf. The fructifications are thicker than those of *Stereum* and their lower surface has numerous minute pores which are readily seen with a pocket lens. Many fungi have such pores, but they are not present in species of *Stereum*. The Canterbury grower said that in his orchard the fungus was found on the varieties Early Orleans and Rivers Early Prolific.

Two Peach Diseases.

A grower who has a number of peach trees, some in the open, trained on walls, and others under glass, complained of losses due to rot attacking the fruit as it approached maturity. A visit to the garden was made, but as it was rather late in the season only a few of the peaches were available for examination. Two types of damage, however, were observed : one was a spotting or pitting which disfigured the fruit ; the other was a soft-rot which reduced the fruit to pulp. A fungus was isolated in culture from the spots, but as it has not yet produced fructifications its identification has not been possible. Those peaches affected with soft-rot bore the fungus *Rhizopus nigricans*, which is known to be a cause of rot in tomatoes, apples and other fruit.

Quince Diseases.

Mildew (*Podosphæra leucotricha*) and Leaf-spot or " Scald " (*Fabræa maculata*) were again present on the type trees in the " Museum " plot, and, as in other years, certain varieties of quince were markedly worse than others.

Varieties which had shown considerable resistance to leaf-spot in previous years again had little of the disease up to the beginning of August, when the most susceptible varieties had nearly all their leaves infected and showed pronounced leaf-fall. As the season advanced, however, conditions so favoured the fungus that by October the more resistant varieties had many infected leaves.

Quince Leaf Blotch (*Sclerotinia cydoniæ*), a disease described in the last Report, was found only on a single leaf of one tree in 1926.

### Mulberry Canker.

Young mulberry trees planted up by a grower in Hampshire had their stems killed back by canker. Specimens sent to East Malling in December were found to be bearing the reddish-brown pustules of *Fusarium lateritium*, which has been shown to be a stage in the life-history of *Gibberella moricola*. This fungus was recorded as killing young shoots of Mulberry at Bognor, Sussex, in 1914, and at Egerton, Kent, in 1916.* As in the case of other cankers, the only sure method of control is to cut out the cankered parts and burn them ; the diseased branches after removal from the trees should not be left lying about or the fungus will continue to develop on them.

### Diseases of Currant and Gooseberry.

White Currant bushes in a garden near West Malling were attacked on the stem near ground level by a fungus, *Fomes ribis*. This, like the plum Fomes, has dark, bracket-like fructifications with small pores on the lower surface.

Black Currant Rust (*Cronartium ribicola*) was not received at this Station in 1925, but in 1926 (as in 1924) there were several enquiries about it. It was found on leaves received from plantations not only in Kent, but also from Sussex and Essex, so that it was probably generally distributed.

Currant Leaf Spot caused by *Pseudopeziza* (*Glœosporium*) *ribis* was again common on black, red and white currants.

Gooseberry Leaf Spot (*Pseudopeziza ribis*) appeared early in the season on the variety trial plot of gooseberries on the Station. In severe cases the leaves were not only badly spotted, but were turning yellow and falling by the middle of June. This was seen on the two varieties Careless and Freedom. Other varieties which showed the disease but were not so seriously infected were Whitesmith, White Lion, Greengage and Gunner. By the middle of July the worst infected bushes showed considerable leaf-fall, many of the young shoots having lost about half their leaves. As with the leaf-spot of currants this disease is usually not considered serious enough for control measures to be taken. In such seasons as the one under consideration however, when the disease causes

* Salmon, E. S., and Wormald, H. " Canker " and " Die-back " Disease of Mulberry. *Gard. Chron.*, 1548. Aug. 26, 1916, p. 95.

such an early and pronounced leaf-fall it must have a weakening effect on the bushes.

### Raspberry Diseases.

Diseased raspberry plants or canes continue to be sent in by growers seeking advice. Specimens showing Blue Stripe Wilt (*Verticillium dahliae*), Cane Spot (*Plectodiscella veneta*), and Mosaic disease have been received from commercial plantations and serious cases of mosaic have been found in private gardens.*

Another disease of raspberries which, in its symptoms, is similar to one known in America as " Spur Blight " has also been under observation. On the young canes the disease may be recognised by purplish blotches which appear mostly at the nodes. In a garden at Maidstone eighty per cent. of the canes in a small plot showed from one to eight of these lesions per cane, when examined in August. During the winter the diseased areas turn grey and finally almost white, but bearing black dots, the fructifications of a fungus *Didymella applanata*. A number of canes of Pyne's Royal on a fruit farm at East Malling also showed the same disease, and canes received from Worcestershire and from Kincardineshire bore the purplish discoloured areas typical of this disease. As information is required respecting the distribution of this disease and the varieties which are attacked we should be pleased if growers seeing this disease in their plantations would send specimens to this Station for examination.

### A Cane Spot of Cultivated Blackberry.

A disease found in a plantation of a cultivated variety of blackberry in East Kent produced symptoms bearing a close resemblance to the Cane Spot (*Anthracnose*) of raspberries. The fungal fructifications present on the spots were more conspicuous than those of anthracnose and the fungus proved to be a species of Septoria, probably *S. rubi*. The spots were grey or almost white with a dark border ; on the leaves they were circular, while on the canes they were elongate (elliptical), the largest being about $\frac{1}{4}$ inch in length.

### Hop Diseases.

The Verticillium Hop Wilt was again found at Penshurst, which is the only locality in which this disease has been found with certainty up to the present. The symptoms of this disease were described in the last Report.†

Another type of hop wilt, which was found in a hop garden at Beckley, Sussex, came to our notice during the year. The fungus associated with this

* A general account giving the symptoms of these diseases appeared in Part I. of the Report of this Station for 1925, and a more detailed description of Blue Stripe Wilt in the Report for 1924.

† See the Annual Report of this Station for 1925, Supplement, p. 92.

disease is a species of *Phoma*, with conidia measuring 4.5-9 by 2-4 $\mu$. The fungus has been isolated in pure culture but its parasitism has not yet been tested.

A disease of hop leaves which appears to be unrecorded for this country was found on a " wild " hop in a hedgerow near East Malling. The diseased leaves showed spots greyish in colour, but bordered by a dark line ; the spots bore fructifications of a species of *Ascochyta*. A fungus *Ascochyta humuli* has been found on the Continent, but whether the one examined here is identical with the Continental species has not yet been determined. About the time of hop-picking a few leaves with similar spots were found in a commercial hop-garden in the vicinity of the infected hedgerow plant.

Hop Downy Mildew (*Pseudoperonospora humuli*) is becoming more widespread. In infected gardens the " spike " stage was common in the spring of 1926. Infection of the leaves of wild Hops was again noted. In September specimens showing infection of the cones were received from localities in Kent and from one place in Hampshire.

### A Wilt Disease of Rhubarb.

A disease of rhubarb which is of interest in relation to the Verticillium wilts of raspberry and hop is one that was found in a garden near Deal in June, and the plants still showed the trouble when the garden was visited in August. The leaves flagged and finally withered prematurely. Associated with the disease was a species of *Verticillium*, fructifications of which appeared within three days on placing pieces of diseased leaf-stalks in a moist chamber.

### Violet Felt Rot of Carrots.

Carrots showing infection with *Rhizoctonia violacea* were found in a garden at East Malling. Of four varieties grown all showed a certain amount of the disease. New Red (Intermediate) was worst and the other varieties in order of severity of attack were Favourite, Inimitable and Early Horn. In the worst cases the roots were almost covered with the fungus and there was arrested development in consequence. Specimens received from another East Malling garden showed the same disease but the roots were not so badly infected and were saleable. This disease is not readily controlled as it is not noticed until the roots are lifted, and, since the fungus attacks a number of vegetables, rotation of crops in a small garden is not likely to be effective. Some years ago Professor Salmon found that the disease could be controlled in the case of seakale by watering the soil with a solution of carbolic acid (1 oz. of carbolic acid to each gallon of water, and 40 gallons used on a plot 19 by 9 feet).

### Bean Scab.

This disease caused by *Colletotrichum lindemuthianum* was found in a Maidstone garden on the variety Canadian Wonder. The outbreak was not

a serious one, and only three plants were infected, though on one of these it was very bad, four beans of one cluster all being badly spotted. As this disease is carried on the seed, seedsmen should not collect the seed from infected plants and growers should sow only sound seeds.

### Walnut Leaf Blotch.

Walnut leaves infected with *Marssonina juglandis* (*Gnomonia ieptostyla*) were received from Faversham and from Devon. As attempts are being made to encourage the cultivation of walnuts in this country, nurserymen should take steps to eliminate this disease from their nurseries as not only is it common on leaves, but it sometimes attacks the young fruit.*

### Hawthorn Leaf Blotch (*Sclerotinia crataegi*).

A disease of hawthorn which is of interest from the fact that it has not previously been recorded for this country and also because the fungus causing it is closely related to those described in the last Report as producing similar diseases on quince and medlar leaves. A single leaf showing the disease was found in a hawthorn hedge at Maidstone. On keeping the twig bearing the leaf in a moist chamber the Monilia stage of the fungus, with "disjunctors" between the spores, appeared as a greyish mould on the upper side of the infected leaf.

### Other Fungal Diseases.

Other diseases, of minor importance, caused by fungi which came under observation were as follows:

Leaf Spot of Horse Radish (*Ramularia armoraciæ*).

Leaf Blotch of Dahlia. The fungus present corresponded closely to *Phyllosticta dahliaecola*, but many of the conidia were septate (slightly constricted at the septa) and in the specimen examined the fungus must be classed as an *Ascochyta*; the conidia measured 7-11 by 3-4 $\mu$

Leaf Blotch of Shasta Daisy (*Septoria leucanthemi*), described in the last Report, where it was recorded from Bearsted and Hayling Island; in 1926 it was found in a garden at Maidstone.

Lilac Leaf Spot (*Phyllosticta syringæ*).

Leaf Spot of Beetroot (*Ramularia beticola*).

Mint Rust (*Puccinia menthæ*) on forced mint at Rustington, Sussex, and in a garden at Harrietsham.

* A brief note on this disease appeared in the Report of this Station for 1924, p. 117.

A Leaf Disease of Kentia Palm. The fungus present on the diseased areas was identified by Miss E. M. Wakefield, of Kew Gardens, as a species of Colletotrichum ; the conidia measured 14-24 by 5-8 $\mu$.

Spotting Caused by a Saprophytic Fungus.

The purely saprophytic fungi, which obtain their nutriment solely from dead organic materials, are generally regarded as harmless to cultivated plants. In February an Arum Lily (*Richardia*) was brought to me with the spathe disfigured by numerous black dots just visible to the naked eye, thus rendering the flowers unsaleable. Similar spots were also present on the leaves. These dots proved to be the spore cases (sporangia) of a species of *Pilobolus*. The members of this genus live on dung, and their sporangia when mature are shot off from their stalks with force enough to carry them some distance above ground so that they are scattered over any vegetation in the neighbourhood. The dung around the Arum plants was apparently infested with this fungus.

Bacterial Diseases.

Bacterial Leaf-spot and " Shot-hole " was extremely common on young Victoria plum trees on the Station and a number of other varieties showed the same trouble to a less extent. Bacterial spots were also found on the young shoots and on the green fruit. An organism has been isolated from the spots and is being studied. Cankers on the stems and branches of plum trees usually resulting in the death of the trees also contain bacteria. An organism has been isolated from such cankers and preliminary experiments have shown that it is able to infect young twigs and branches ; further experiments are being carried out to ascertain whether the larger cankers are primarily and entirely due to bacterial infection.

Walnut Bacterial Leaf-spot was again found on a few young trees planted up on the Station. There is good evidence, from inoculation and cultural experiments, that this disease is identical with the Bacterial Blight which is so detrimental to walnuts in California.

Virus Diseases.

Mosaic disease has again been conspicuous on certain varieties of raspberry and has been found in commercial plantations and in private gardens. In a garden at Goudhurst every plant of two rows of raspberries was infected with mosaic.

A case of mosaic disease in tomatoes was reported to the Station by a grower at West Malling. All the plants (variety Comet) in two large houses were infected, while a few plants of the variety Fillbasket in another house also showed the disease. Specimens were sent to Dr. Bewley of the Cheshunt Research

Station, where tomato mosaic has been under investigation for some years. Dr. Bewley reported that the type of mosaic in question was not serious if care was taken to obtain proper cultural conditions, and he advised a certain line of treatment which was carried out with success.

Specimens of dwarf beans received from Hereford showing the mottling typical of mosaic disease. The plants had been raised from seed obtained from Holland and were of the " Mangetout " kinds. The varieties were " Perfect zonder draden " and " Roem van Holland."

# BURR-KNOTS.*

By R. G. HATTON, H. WORMALD and A. W. WITT.

Certain types of excrescences, common on apple trees, but also found on other kinds of trees, have long been known to fruit-growers and nurserymen as "Burr-knots" or "Root-knots." They are typically tumourous swellings with papilla-like out growths such as shown in Fig. 7. In this country they have been looked upon as characteristic of certain varieties of fruit trees, particularly those which produce roots freely when propagated by cuttings; in fact the papillæ are regarded as incipient roots which are arrested in development but resume growth when placed in moist soil and so develop into functional roots. This habit of burr-knotted trees has been well-known to English growers from the seventeenth century onwards. Comparatively recently, however, it has been suggested in America that such aerial tumours are a form of Crown-gall, which is a definite disease condition now known to be caused by bacteria, as first shown by Dr. Erwin F. Smith and his collaborators at the United States Bureau of Plant Industry. Since a number of the types of apple stocks raised at East Malling show conspicuous burr-knots when allowed to grow into trees our interest was drawn to the matter as we were anxious to ascertain whether there were any real grounds for assuming that the knots were caused by a parasite identical with, or related to, the crown-gall organism *Bacterium tumefaciens*.

Root-initials on the aerial parts are of frequent occurrence on a number of different kinds of plants. They may be seen on vines and tomatoes, and Professor Borthwick† describes them on a number of trees in which they cause the wood to assume the condition known as "Bird's eye," as, for example, in the maple. When such "adventitious" roots arise in clusters in a swollen base they produce the burr-knot condition. On fruit trees, in addition to the apple, they are common on the quince, and aerial root-initials with an approach to aggregation into knots are to be found on some plum varieties. Recently typical examples of burr-knots on Portugal laurel were sent to us by Mr. Hotson from Devonshire.

The knots assume different forms according to the variety of tree on which they are found. On our apple Type IV. they remain smooth and rounded until they reach a size of about two inches, when they become irregular with the

* This article is a resumé of a more detailed paper which appeared in the Journal of Pomology, Vol. V, 1926, pp. 195-204.

† Borthwick, A. W. The Production of Adventitious Roots and their Relation to Bird's-Eye Formation (Maser-Holz) in the Wood of Various Trees. Notes, Roy. Bot. Gard. Edinburgh. No. XVI, 1905, p. 15-36.

Professor Borthwick's paper, not mentioned in our original article, was brought to our notice by the editor of "Nature."

appearance of warty projections, the root-initials, on their surface. On Type I. (Broadleaf), however, the knots are very irregular almost from their first appearance, the incipient roots showing on the very young knots. In the latter kind the root-initials are at first very few, but they increase in number with the age of the knot until eventually a typical " burr " is formed. This form of knot is also shown by Crab J (Fig. 7), Type II. (Doucin) and Type V. (Doucin Amélioré). Knots intermediate in form occur on other varieties of apple ; these are rounded at first, but soon root-initials appear and they become irregular.

The knots are often several feet above the ground and on trees at East Malling, about fifteen years old, they are to be found from ground level to six feet above the ground.

Certain well-known commercial varieties of apple in this country produce these knots readily, such as, for instance, Oslin, Kentish Codlin, Manx Codling, and Warner's King. The knots are also well-known to horticulturists on the Continent and in America. English growers have generally associated them with free-rooting, and branches bearing burr-knots have often been used for propagating those varieties of apples which produce them.

Since each burr is a clustered mass of root-initials (which grow out as roots under favourable conditions) it produces, when planted up, a tuft of roots. Hedgcock, an American worker, compared such dense clusters of roots with " Hairy Root " and assumed therefore that they were a symptom of disease brought about by infection with the crown-gall organism. More recent work in America has failed to confirm Hedgcock's conclusions. Numerous culture plates prepared from aerial knots by Miss Nellie A. Brown at the United States Bureau of Plant Industry yielded in no case the crown-gall organism and she concluded therefore that such knots were not a form of crown-gall. Swingle has also made a study of burr-knots in relation to their occurrence on American varieties of apples, and he too is of the opinion that they are not crown-gall.

Experiments carried out at East Malling lead us also to conclude that the knots found on English varieties of apples are not of a pathological nature, but that they are a characteristic feature of certain varieties and that they generally denote free-rooting. Repeated attempts were made to isolate the crown-gall organism from knots both of the rounded and the irregular forms, but without success. In order to test their ready-rooting habit branches bearing knots were cut off and planted out, some in pots in the greenhouse, others in the open ground. Of nineteen cuttings planted in pots fifteen rooted well and produced healthy trees ; of twenty-six planted in the open twenty-one rooted and lived. The greatest success was obtained with those knots on which the root-initials appear early. Thus of nine cuttings of Crab J and ten from Crab B (two types which produce typical burrs), all gave rise to well-rooted trees. Of eleven cuttings of Type IV., however, a type which produces the smooth, rounded form of knot,

FIG. 1.
A " Crab " stock, showing Burr-knots on the stem.

FIG. 2.
Burr-knots on Quince.

FIG. 3.
Root rudiments on Plum Stems.

FIG. 4.
Burr-knots on Apple Stock Type IV., showing incipient roots on the older knots only.

FIG. 5.
Young knots on Apple Stock Type IV., showing their smooth contour.

FIG. 6.
Similar knots to those in Fig. 4, bearing roots eight weeks after being planted up.

FIG. 7.
Burr-knots on Apple Stock Type J., showing incipient roots even on the very young knots.

FIG. 8.
The branch shown in Fig. 7 but eight weeks after being planted up: the knots have produced roots and the buds above the ground have developed into healthy shoots.

only three grew into well-rooted trees, five did not grow at all, and two produced a few roots only, without making any growth above ground.

Some of our Paradise (layered) stocks, although they do not produce aerial knots, develop, on the layers, tufts of roots rather resembling those that grow from burr-knots. This again is a characteristic feature of those particular types and is not a condition of disease. Some of these types of stocks, however, when sent to America were destroyed at the port of entry under the suspicion that they were infected with hairy-root.

The recent study of burr-knots in America and in this country go to show, therefore, that these aerial outgrowths known as burr-knots are not a pathological condition but that they are in fact a desirable feature of many stocks in that they promote free rooting.

# CANKER IN FERTILITY PEAR TREES.*

By H. WORMALD.

The Fertility variety of pear, on account of its regular and heavy bearing, has been extensively planted in certain districts. Many growers, however, complain that this variety is so subject to canker, particularly when worked on seedling free pear stocks, that it is impossible to grow it as a standard tree.

## A Cause of Failure.

Recent observations made at East Malling suggest one reason for the failure of this variety to develop satisfactorily into good standard trees. At the Research Station there is a trial plot of the Fertility pear, standard and bush trees worked on various stocks, the trees being now seven years old. During the spring of 1926, they came into leaf and flower apparently normally, but shortly afterwards, early in May, on many of the trees, a number of branches showed wilting leaves and flower trusses. The standard trees were far worse, in this respect, than the bush trees, for while many of the former had large branches (about three feet long), showing the disease, the trouble on the bush trees was comparatively slight. The most conspicuous examples were certain standard trees on which the main " leader " was dying back, as in the tree shown in Fig. 1, the head of the tree with withered leaves contrasting with the rest.

In every case examined, there were lesions caused by the pear scab fungus (*Venturia pirina*) at the lower end of the dying portion. Where a spur was killed, there were scab lesions on the spur itself or at the base where it joined the branch, and many of them showed, in addition, an obvious canker round the base of the spur. These cankers were still more evident on the affected branches, and, in every instance where a branch was dying back, there were present the comparatively superficial scab lesions and the more deeply penetrating cankers caused by the canker fungus (*Nectria galligena*).

The cankered areas on the branches were sometimes six inches long (Fig. 2). They bore numerous irregular cracks, in which the dark brown scab pustules could readily be seen with a lens. Some of the cankers also showed the whitish pustules of the " summer stage " of the canker fungus, and, on others, such pustules developed in a few days on keeping the cankers in a moist chamber.

## Canker and Scab Fungi Both Present.

In no case was any canker found on these trees without the presence also of the scab lesions. This fact suggests that, in this particular outbreak, the

* This article appeared in the Journal of the Ministry of Agriculture, Vol. XXXIV, No. 2, pp. 162-165, May, 1927, and is reprinted here by permission of the Ministry and H.M. Stationery Office.

predisposing cause leading to the death of the branches was the infection of the young twigs by the scab fungus ; this allowed the canker fungus to gain an entrance, through the scab wounds, and infect the woody parts, thus cutting off the upward flow of sap to those parts of the tree terminal to the cankers.

Wiltshire,* when studying the relation of scab infections to the incidence of cankers in apple trees, found that the canker fungus is able to gain an entrance through scab wounds, and the observations on the trees under consideration show that a similar result obtains in pear trees.

All parts showing definite evidence of infection by the canker fungus were cut away,† but there was still left a considerable amount of bark badly infected by scab, though not, at the time, showing canker. When the trees were examined in July, some weeks after the cankers had been removed, it was seen that the scab lesions which remained were quite superficial and were being cut off by a corky layer below. On rubbing the bark, the scaly layers were easily removed, leaving a healed scar.

Few of the standard trees were entirely free from cankers, and one or more branches had to be cut out from most of them. On the bush trees, however, canker was almost negligible ; on these, with the exception of one tree from which one small branch had to be removed, the few cankers present were confined to small shoots or spurs. The probable explanation of the comparative freedom from severe canker attack shown by the bush trees is that these had been annually "leader-tipped" and spur-pruned, so that those parts of the young shoots, liable to infection with scab, were mostly removed during the ordinary pruning operations ; the leading shoots of the standard trees, on the other hand, had been allowed to " run " for several years, and the trees had merely received slight thinning.

### Influence of the Stock in Predisposing to Infection.

Whether the type of stock used has any influence on the degree of infection in this form of canker infection cannot, perhaps, be stated with certainty, but the records taken of the number of cankered branches removed from each tree suggest that, when grown as standard trees on certain stocks, Fertility pear trees are very susceptible. The stocks used for the standard trees in the trial plot, on which these observations were taken, were seedling hawthorn, mountain ash, wild service, white beam, common seedling pear, and seedling wild pear. One or more of the trees on each stock showed cankered branches and spurs, but those on

* Wiltshire, S. P. "Canker Infection of Apple Trees through Scab Wounds," *Annals of Applied Biology* IX, 1922, pp. 275-281.

† The writer wishes to take this opportunity of expressing his indebtedness to Mr. A. C. Painter who personally cut out the cankered branches and recorded the number removed from each tree.

common pear were, on the whole, far worse than those on other stocks. Two trees, the worst of all, were on this stock; from each of these two trees five large branches had to be removed together with a number of smaller branches, shoots and spurs. On the bush trees the amount of canker was too small for the records to give clear indications that the type of stock had any influence on the degree of infection.

The trees on common and wild pear stocks had made the most vigorous growth, a fact which seems to indicate that growing this variety on a stock inducing vigour makes it more susceptible to attack by this form of disease.

### Control Measures.

To summarise the foregoing observations, there are, at the Research Station, two sets of trees (both on a similar series of quince and free pear root-stocks), one set grown as standards with 4 ft. 6 in. length of stem, and the other as bush trees with a stem of 2 ft. Both sets are interplanted on this same experimental plot, the only difference in treatment being that the bush trees have had the leading branches tipped and the laterals spurred annually. The standard trees have been seriously crippled by canker, while the bush trees have been practically free from it.

It would appear, therefore, that the grower, who wishes to cultivate Fertility pears, has two alternatives: either to grow bush trees, on which the normal operations of leader tipping and pruning reduce, indirectly, the liability to scab infection and subsequent canker; or to grow standard trees, which cannot be so economically or effectively pruned and sprayed, and will also need considerable attention to keep them free from cankering.

The observations at East Malling go to show clearly how much more effectively canker in Fertility pears can be controlled when the variety is grown as a regularly pruned bush; it is this, rather than choice of stock, which is the deciding factor in producing healthy trees.

It must be remembered that scab itself causes serious disfigurement of the fruit, and systematic spraying, to control scab infection of fruit, leaves and shoots, should be routine practice. Since, as shown here, such infections on the shoots lead the way to canker, effective spraying against scab will also reduce canker. If, therefore, the grower decides on standard trees special attention must be given to the spraying operations, particularly as standard trees soon get so tall that, to reach the uppermost branches, a high-pressure power sprayer is required. Bordeaux mixture is the best fungicide at present known for use against scab, and it can generally be used with perfect safety on pears. The first spraying should be carried out just before flowering and the second immediately the fruit is set. When trees have been seriously infested the previous year, or where subsequent canker infection is feared, later sprayings should not be neglected.

FIG. 1. FIG. 2.

FIG. 1.

A Fertility Pear Tree with dead branches. The leading branches at the top show the disease most conspicuously.

FIG. 2.

The type of canker causing the disease. The irregular cracking of the bark is due to the Pear Scab fungus. The white pustules are the conidial fructifications of the canker fungus.

If cankers make their appearance, they should, as a matter of course, be cut out at the earliest opportunity.

## NOTE.

Since the original publication of this article the conclusions arrived at above have been confirmed by observations on a row of ten Fertility trees, all on the same stock (Angers Quince), pruned and unpruned trees alternating in the row. These trees (planted as " maidens " in 1923) became infected with scab in 1927 and this was followed by canker, so that in the spring of 1928 many cankered branches had to be cut away. The amount of " wood " cut from the unpruned trees was about four times that from the pruned trees. Before this operation was carried out there was a striking contrast between the unpruned trees, with large branches bearing withered leaves, and the pruned trees showing comparatively little damage.

Results even more striking were observed on a similar row of ten trees of the variety Georges Bouchier, also on Angers Quince. In this case again pruned trees alternated with unpruned trees. On the pruned trees one canker only was found, the amount of wood cut away because of it weighing approximately half an ounce. The wood which had to be cut out from the unpruned trees, by reason of the cankers present, varied from 4 to 40 ounces with an average of 21 ounces per tree.*

* The records of the trees mentioned in this note were taken by Mr. J. Amos.

# PRELIMINARY REPORT ON THE INCIDENCE AND CONTROL OF APPLE SCAB AND APPLE MILDEW.

By A. M. FRAMPTON.

The following report is based on observations made during the spring and summer of 1926 on a plot of apple trees of the varieties Cox's Orange Pippin and Stirling Castle on the East Malling Research Station. This plot, planted in 1922 for stock trials, consists of alternate rows of Cox's Orange Pippin and Stirling Castle, these varieties, as scions, being worked on a number of different stocks. The plot had received uniform treatment until the spring of 1926 when the spraying trials commenced. These trials were designed to test the efficacy of various spray fluids in controlling apple scab and mildew on two valuable varieties which are very susceptible to spray injury.

## Observations on Apple Scab and Mildew during the Dormant Season.

In March, directly after the trees were pruned, observations were made on the twig infections of scab and mildew on the prunings from each tree on the plot. . As the trees had received uniform treatment up to this time the observations were made with the object of ascertaining whether the type of stock had any influence on the degree of infection.

### (*a*) *Scab.*

It was found possible in most cases to count the scab infections individually, but where the spots ran into each other so that the separate infections were indistinguishable the length of the patches was estimated. The number of infections left on the tree after pruning were also counted.

Instances were frequently noticed where a badly infected tree was between two trees on another stock which had remained almost free from scab, and this difference in the degree of infection was maintained fairly consistently throughout the row, but exceptions did sometimes occur. When the figures for all the trees on each stock, however, are taken into consideration, the differences in susceptibility in relation to types of stock are found to hold good. This is seen by dividing the trees on each stock into three arbitrary classes :—

A. Infection relatively slight—with under 30 scattered spots.

B. Infection moderate—30 or over, but less than an inch of massed scab.

C. Infection severe—1 inch and over of massed scab.

## Table I.

*The following table gives the percentage of trees of Cox's Orange Pippin on each stock which falls into each of the three classes :—*

| | Types of Stocks used for Cox's Orange Pippin. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | III. | XIII. | VI. | I. | II. | XV. | X. | XVI. | V. | IV. | IX. |
| No. of Trees. | 16 | 16 | 16 | 16 | 16 | 8 | 15 | 16 | 16 | 8 | 16 |
| A. Infection slight .. .. .. | 93.8 | 80.6 | 80.0 | 75.0 | 68.6 | 62.5 | 46.8 | 43.7 | 31.2 | 14.3 | 31.2 |
| B. Infection moderate .. .. | — | — | 13.3 | 12.5 | 25.0 | 12.5 | 26.6 | 31.3 | 31.3 | 57.2 | 6.3 |
| C. Infection severe .. .. | 6.2 | 19.4 | 6.7 | 12.5 | 6.4 | 25.0 | 26.6 | 25.0 | 37.5 | 28.5 | 62.5 |
| | Relatively Resistant. | | | | | | | Very Susceptible. | | | |

It is generally acknowledged that Cox's Orange Pippin is very susceptible to scab infection of the young shoots ; this is confirmed by the observations here recorded. The figures suggest, however, that the degree of infection varies to some extent with the type of stock on which the variety is worked. The Stirling Castle trees were free from scab infection of the shoots.

(*b*) *Mildew.*

There were a few mildewed shoots on nearly every tree of Cox's Orange Pippin on each stock, and no differences in susceptibility could be distinguished. On the Stirling Castles there was less mildew, on certain types *e.g.*, XVI, VI and IX practically none.

A record was also taken of the number of mildewed buds when they were bursting in April, but again no significant differences were found.

Spraying Experiments on Cox's Orange Pippin.

The experiments were designed to compare :—

I. The fungicidal properties of various spray fluids.

(1). Lime Sulphur and Bordeaux Mixture.

(*a*). With lead arsenate.

(*b*). Without lead arsenate.

(2). Lime Sulphur and Colloidal Sulphur.

II. The influence of the root-stock on the fungicidal effects.

III. The effect of the time of application and number of applications of each fungicide.

(1). Pre-blossoming only.

(2). Pre-blossoming and post-blossoming.

(3). Post-blossoming only.

IV. Injurious effects on the tree of the various spray fluids.

V. The influence of the root-stock on spray injury.

In each experiment a third of the number of available trees on each stock which were to be used for the comparison of two spray fluids was left unsprayed (or sprayed only with lead arsenate) to act as a control. The trees chosen to receive any one treatment were scattered as widely as possible in order to minimize the influence of local soil peculiarities.

The weather conditions at the time of spraying were observed for comparison with other years, as it has been suggested that the injurious effects of the fungicides on the foliage may be dependent, to some extent, on the amount of sunshine immediately following spraying.

*Pre-blossoming sprays.*

The pre-blossoming sprays were applied on April 9th when the blossom buds were about to open (pink stage). The spray fluids used were :—

Lime sulphur 1:29 + lead arsenate, 4 lbs. in 100 gallons.

Bordeaux Mixture 8-8-100 +lead arsenate, 4 lbs. in 100 gallons.

The sprays were applied to trees on types I, II, IX, XVI, III and XV, the control trees being sprayed with lead arsenate (4 lbs. in 100 gallons). The trees on type IV, received similar treatment but with the lead arsenate omitted, the control trees being left unsprayed.

*Post-blossoming spray.*

This was applied on May 31st, when the blossom was over, and when in a normal year the fruit would have been set. The lime sulphur was used weaker than before *i.e.*, at a concentration of 1:100, with lead arsenate 3 lbs. to 100 gallons and the Bordeaux Mixture was used with excess lime (8-25-100).

The sprays were applied as before to trees on types III, XV, (with lead arsenate), and IV (without lead arsenate) and, in addition, those on types V and XIII, which had not received pre-blossom sprays, were also sprayed. The trees on types VI and X were given lime sulphur 1:150, and colloidal sulphur 5 lbs in 100 gallons, both with gelatine as a spreader, and the control trees were left unsprayed.

The post-blossoming spray was repeated on July 13th.

Comparison of Fungicidal Properties of Spray Fluids Used.

The method adopted for estimating the value of the various sprays in controlling scab was to find the percentage of leaves on each tree which showed scab a certain time after spraying. It was not found possible to count all the leaves on all the three hundred trees, so one representative branch of a reasonable size was taken. On each tree the lowest branch of the third order was chosen ; the total number of leaves was counted and the number of those showing scab was also ascertained. This was done just before the second spraying, for the trees on all the types which had received the pre-blossoming spray, *i.e.*, seven weeks after the first application. On types II. and XVI. the counts were not made owing to lack of time. It was repeated on all the trees a month later.

The results can be seen most clearly in Table II., which gives the average percentage of infected leaves under each treatment for comparison with the untreated trees.

It is shown that : (1) Lime sulphur of the strength (1 : 29) used for the pre-blossoming spray gave almost complete control of scab for seven weeks, there being in most cases less than 1 per cent. infected leaves, but the effect had nearly disappeared after eleven weeks. (2) Bordeaux mixture 8-8-100

## Table II.

*Percentage of Leaves Infected with Scab after Spraying.*
*Cox's Orange Pippin.*

L.S.=Lime sulphur. C.S.=Colloidal Sulphur. G.=Gelatine.
B.M.=Bordeaux Mixture. A.=Lead Arsenate.

Pre-blossoming Spray (applied 9/4/26).

| Stock. | Treatment. L.S.A. (1:29). | B.M.A. (8-8-100) | Control A. | Date. |
|---|---|---|---|---|
| I. .. .. | .69 | 2.49 | 23.41 | 31/5/26 |
| | 22.24 | 26.33 | 38.33 | 29/6/26 |
| II. .. .. | | | | |
| IX. .. .. | 2.76 | 5.46 | 16.16 | 31/5/26 |
| | 28.33 | 28.04 | 47.56 | 29/6/26 |
| XVI. .. .. | | | | |

Pre-blossoming and Post-blossoming Sprays.

| Stock. | Treatment. L.S.A. | B.M.A. | Control A. | L.S. | B.M. | Control. | Date. |
|---|---|---|---|---|---|---|---|
| III. .. | .66 | 1.91 | 15.53 | | | | 31/5/26 |
| | 9.72 | 2.25 | 34.57 | | | | 29/6/26 |
| XV. .. | .41 | 4.03 | 20.00 | | 3.76 | | 31/5/26 |
| | 6.80 | 2.67 | 27.21 | | 1.37 | | 29/6/26 |
| IV. .. | | | | .57 | 5.75 | 9.81 | 31/5/26 |
| | | | | 2.83 | 3.41 | 33.80 | 29/6/26 |

Post-blossoming Spray only (applied 31/5/26).

| Stock. | Treatment. L.S.A. (1:100) | B.M.A. (8-25-100) | Control A. | L.S.G. (1:150) | C.S.G. | Control. | Date. |
|---|---|---|---|---|---|---|---|
| V. .. | 19.23 | 4.92 | 38.40 | | | | 29/6/26 |
| XIII. .. | 5.51 | 3.40 | 23.63 | | | | 29/6/26 |
| VI. .. | | | | 18.56 | 32.87 | 31.95 | 29/6/26 |
| X. .. | | | | 27.15 | 33.66 | 36.14 | 29/6/26 |

acted as a very efficient fungicide also, the average number of infected leaves seven weeks after spraying being in all cases less then 6 per cent. (3) Bordeaux mixture with excess lime proved slightly more effective than lime sulphur 1:100. (4) Lead arsenate did not appear to increase the fungicidal effect of lime sulphur or of Bordeaux mixture. (5) Colloidal sulphur, at the strength used had no fungicidal effect. (6) No stock influence on leaf infection could be distinguished, at any rate on the one summer's observations.

It was hoped to be able to augment these results by observations on the amount of disease on the fruit, but the cold winds in the spring prevented the setting of the fruit and the crop was negligible.

### Injurious Effects of Spray Fluids on the Tree.

After the application of the fungicides, observations were made to discover whether any damage was caused to the trees.

#### *Pre-Blossoming Spray.*

It was found that four days after the pre-blossoming spray was applied the youngest leaves on the trees on all stocks which had been treated with lime sulphur (1:29) and arsenate were brown at the edges as though they had been scorched. Neither the Bordeaux mixture and arsenate nor the arsenate alone caused any damage at this stage.

#### *Post-Blossoming Spray.*

As soon as leaf-fall began after the second spraying, it was found impossible to make accurate numerical observations on the fallen leaves without devising some means of preventing those from different trees becoming mingled by the wind. The method adopted was to erect troughs made of Hessian round the trees. The troughs were made as uniformly effective as possible by taking equal, squares of Hessian (42 in. sq.), attaching them to the tree in the centre immediately below the division of the first branches, and stretching the sides of the squares to their utmost limit. Thus, though the troughs might vary slightly in their distance from the ground, they bore a uniform relation to the branches of the tree. The troughs were made rigid by attaching the sides of the squares to horizontal canes, supported at the corners on posts inserted in the ground at a given distance from the tree. It was found that the leaves were caught by this method and were retained even in a high wind. The cost of Hessian, however, necessitated the erection of the troughs being confined to only a few representative trees from each experiment, viz., three from each treatment (without regard to rootstock) in each of the three groups of experiments.

The method was adopted too late, however, for this season's results to have

much significance, because the week after leaf-fall (caused by the first post-blossoming spray) had begun, was taken up by the erection of the troughs, and during that time the fallen leaves were not counted.

A week after spraying no damage could be observed on any of the trees which had also received the first application, nor on the trees on Types VI. and X. which received weak lime sulphur (1:150) and colloidal sulphur, but had not been treated before. But on Type V. the trees which had been treated with Bordeaux mixture and arsenate showed a blackening of some of the older leaves four days after spraying in a manner which suggested that the blackened patches might be the areas already infected with scab. Three days later leaf-fall was beginning on all the trees on Type V., and was greatest on those treated with Bordeaux mixture and arsenate. By this time also the trees on Type XIII. which had received Bordeaux mixture and arsenate showed a blackening of the older leaves in the same way as had occurred earlier on Type V. Types V. and XIII. had received similar treatment, so that the fact that this appeared earlier on V. than on XIII. seems to indicate possible stock influence.

This blackening was noticed only on the trees on Types V. and XIII., which received Bordeaux mixture as a post-blossoming spray only, and seems to indicate in a negative way that the pre-blossoming spray may have had some protective influence, as suggested by Petherbridge and Dillon Weston (Journ. Min. Agric., March, 1926). There is some positive evidence of this shown in the figures for the leaf-fall on Type III., a week after the third spraying. The trees sprayed with Bordeaux mixture and arsenate show considerably fewer fallen leaves than those sprayed with either lime sulphur and arsenate or arsenate alone. (Table III.)

When the leaf-fall on Type V. a week after the second spraying is compared with that a week after the first spraying (Table IV.), it is seen that whereas most damage was caused by Bordeaux mixture and arsenate after the first application, after the second application far fewer leaves fell from the trees, so treated, than from those treated with lime sulphur and arsenate.

Table III. shows also that either the Bordeaux mixture was having a directly advantageous effect in keeping leaves attached longer than was normal, or, as does not seem probable from other figures, that the lead arsenate alone was injurious.

A fortnight after spraying slight leaf-fall had begun on the trees on Type III. which had been treated with lime sulphur and arsenate, and on Type X., both on the trees which had received lime sulphur and those which had received colloidal sulphur.

The next day leaf-fall had begun also on the trees on Type III. which had been treated with Bordeaux mixture and arsenate, but in the case of one of the controls as many leaves had fallen as from any of the trees which had had this

TABLE III.

| | Lime Sulphur and Arsenate. | | | Bordeaux Mixture and Arsenate. | | | Arsenate only. | | |
|---|---|---|---|---|---|---|---|---|---|
| Tree. | R9.5 | R9.11 | R10.10 | R9.7 | R9.13 | R10.12 | R9.3 | R9.9 | R10.8 |
| Number of fallen leaves, 20/7/26 | 370 | 269 | 484 | 77 | 5 | 62 | 297 | 134 | 283 |
| Average Number per tree .. | 374.3 | | | 48.0 | | | 238.0 | | |

spray. Considerable individual differences were frequently found among trees which had received similar treatment.

General observations made later in the season, when leaf-fall induced by spraying had ceased, showed that all the sprays containing sulphides or colloidal sulphur caused marked leaf-fall ; this was particularly noticeable on the trees sprayed with lime sulphur, either alone, or mixed with gelatine or with arsenate of lead.

TABLE IV.

| Row. | Tree. | Treatment. | No. of fallen leaves a week after 1st. spraying. | Average fall per tree a week after 1st. spraying. | No. of fallen leaves a week after 2nd. spraying. | Average fall per tree a week after 2nd. spraying. |
|---|---|---|---|---|---|---|
| 3 | 5 | L.S.A. | 52 | | 725 | |
| 3 | 11 | ,, | 23 | | 375 | |
| 16 | 4 | ,, | 11 | 22.0 | | 487.0 |
| 16 | 10 | ,, | 13 | | 361 | |
| 16 | 16 | ,, | 11 | | | |
| 3 | 1 | B.M.A. | 43 | | | |
| 3 | 7 | ,, | 62 | | 156 | |
| 3 | 13 | ,, | 54 | 42.4 | 161 | 156.0 |
| 16 | 6 | ,, | 23 | | 151 | |
| 16 | 12 | ,, | 32 | | | |
| 3 | 3 | A. | 7 | | | |
| 3 | 9 | ,, | 2 | | 155 | |
| 3 | 15 | ,, | 7 | | | |
| 16 | 2 | ,, | 0 | 3.0 | | 85.5 |
| 16 | 8 | ,, | 2 | | 16 | |
| 16 | 14 | ,, | 0 | | | |

SPRAYING EXPERIMENTS ON STIRLING CASTLE.

These experiments were designed to compare the properties with regard to Mildew control and spray injury of the following spray fluids :

(1) Lime Sulphur : Ammonium Polysulphide.

(2) Ammonium polysulphide with gelatine or soap as spreader.

(3) Lime Sulphur : Liver of Sulphur.

(4) Lime Sulphur : Colloidal Sulphur.

Also to observe, as with the Cox's Orange Pippins, the influence of the rootstock, and of the time of application and number of applications of the spray fluids, on their fungicidal and defoliating properties.

The *Pre-Blossoming Spray* was applied on April 9th to the trees on Types I., II., IX., XVI., XI. and XV. Lime sulphur 1:29 and ammonium polysulphide 1:100 were used, with gelatine as spreader. The control trees were left unsprayed.

*The Post-Blossoming Spray* was applied on May 31st. The trees on Types XI. and XV. received LS. 1:100 and APS 1:200, both with gelatine.

The trees on Type IV. received APS 1:200, some with soap and some with gelatine as spreader.

The trees on Types V. and XIII. received LS. 1:100 with gelatine and liver of sulphur with soap.

The trees on Types VI. and X. received LS. 1:150 or colloidal sulphur, both with gelatine.

The post-blossoming spray was repeated on July 13th, and this time some of the control trees were sprayed with water.

There was so little mildew on the trees that no estimation of the fungicidal qualities of the spray fluids could be obtained this year. The records are therefore confined to leaf-fall and the methods used were the same as for the Cox's Orange Pippin.

### Pre-Blossoming Spray.

The LS. (1:29) caused a slight scorching of the youngest leaves, as it did with the Coxs. The APS caused no damage.

### Post-Blossoming Spray.

Table V. gives the average total fall per tree during the week following the first application of the post-blossoming spray and during the week following the second application. The first column shows that lime sulphur caused the most defoliation, even when the strength used was only 1:150. Ammonium polysulphide caused some leaf-fall, there being no difference according to whether soap or gelatine was used as the spreader. Liver of sulphur appears from the table to have caused no damage, but in reality the injurious effects appeared later, starting twelve days after spraying, when the fall from the trees with other treatments was stopping, and continuing steadily for a fortnight, till the final damage was as great as with lime sulphur. After the second application the results are taken only from the trees with troughs. A striking difference is seen this time between the effects of ammonium polysulphide with gelatine and with soap, but the average for the former was sent up by the damage caused to one tree, and stock influence is not ruled out.

There is not much evidence for or against stock influence on the reaction of Stirling Castle to spray fluids, because in no case did more than two types receive the same treatment. There was a noticeable difference, however, in the damage to Types XI. and XV. treated with ammonium polysulphide. The average total fall per tree during the week after the first post-blossoming spray on Type XI., was 17.0, and on Type XV. it was 80.3.

TABLE V.

*Showing Average Number of Fallen Leaves per Tree.*

| Treatment. | June 7th. | No. of Trees. | July 20th. | No. of Trees. |
|---|---|---|---|---|
| Lime Sulphur (1/100) and Gelatine .. | 183.5 | 13 | 164.7 | 6 |
| Lime Sulphur (1/150) and Gelatine .. | 110.6 | 7 | 100.6 | 3 |
| Ammonium polysulphide and Gelatine | 61.8 | 6 | 105.5 | 4 |
| Ammonium polysulphide and Soap .. | 61.0 | 2 | 34.0 | 2 |
| Liver of Sulphur .. .. .. | 11.3 | 7 | 37.3 | 3 |
| Colloidal Sulphur .. .. .. | 8.8 | 7 | 27.0 | 3 |
| Control .. .. .. .. | 3.0 | 29 | 15.9 | 9 |

SUMMARY.

A. COX'S ORANGE PIPPIN.

1. This variety is very susceptible to wood infection by the scab fungus, but the stock on which it is worked has considerable influence on its power of resistance.

2. Scab was controlled on the foliage for seven weeks by a pre-blossoming application of either lime sulphur 1:29, or Bordeaux mixture 8-8-100, the lime sulphur being slightly more efficacious.

3. A further application after blossoming of lime sulphur 1:100 or of Bordeaux mixture 8-25-100 proved similarly fungicidal, the Bordeaux mixture being slightly more efficacious.

4. The presence or absence of lead arsenate had no appreciable influence on the fungicidal properties of lime sulphur and Bordeaux mixture.

5. Colloidal sulphur, at the strength used, did not control scab.

6. No appreciable influence could be detected on the influence of the stock on the susceptibility of the foliage of the scion to infection by the scab fungus.

7. The pre-blossoming spray with Bordeaux mixture 8-8-100 caused no damage to the foliage.

8. The pre-blossoming spray with lime-sulphur 1:29 scorched the young leaves, but caused no defoliation.

9. The post-blossoming application of both lime-sulphur 1:100 and Bordeaux mixture 8-25-100, caused considerable dropping of the older leaves, but Bordeaux mixture caused far less defoliation of the younger leaves than lime sulphur.

10. There were indications that one application of Bordeaux mixture protected the foliage to some extent against injurious effects from a second application.

11. There were indications that the stock exerts some influence on the amount of spray injury.

B. Stirling Castle.

1. A pre-blossoming spray with ammonium polysulphide 1:100 caused no damage to the foliage.

2. A pre-blossoming spray with lime sulphur 1:29 scorched the young leaves but caused no defoliation.

3. A post-blossoming spray with lime sulphur 1:100 and with colloidal sulphur caused considerable dropping of the young leaves.

4. A post-blossoming spray with ammonium polysulphide 1:200 caused some leaf-fall, but less than that caused by lime sulphur 1:150.

5. A post-blossoming application of liver of sulphur caused little defoliation.

6. No significant difference was observed between the extent of the damage caused by one and two applications of any treatment.

7. The data at present available are insufficient for conclusions to be drawn with regard to stock influence on spray injury.

# NOTE ON "BLACK ROT" OF CRUCIFEROUS PLANTS.

By H. WORMALD and A. M. FRAMPTON.

In October, 1925, when examining the young plants in seed beds of various cruciferous crops on this Station, we noticed that the leaves on a number of broccoli plants showed symptoms of a disease that in America is known to be very destructive to cabbages, turnips and related plants. The symptoms observed were yellowish patches starting at the edges of the leaves and extending towards the midrib, the veins in these diseased areas being very dark in colour and showing up as black lines on the yellow parts of the leaves (Fig. 1). As the disease extended the affected leaves became withered and fell off. Microscopic examination showed that the blackened veins were crowded with bacteria.

These symptoms, which we found on broccoli (variety Michaelmas White), and on savoy (variety Best of All), corresponded to those of the disease known "Black Rot of Cruciferous Plants," caused by the bacterium *Pseudomonas campestris* (=*Bacterium campestre*)*; which has been studied in detail by American workers. In such plants as cabbage, broccoli and savoy the disease is recognised by the characters mentioned above. In root crops (turnips and swedes) the root is invaded and turns dark brown internally, although the rind remains firm; this type of injury has been described as "Black Dry Rot," or "Brown-rot."

Although this disease has been reported in this country from time to time we have not found a detailed description of the organism (as found in Britain) accompanied by inoculation experiments, sufficient to establish completely the identity of the parasite with the bacterium which has been studied by American plant pathologists.

In 1902 Middleton† recorded a "Black Dry Rot" which infected nearly every plant in a four acre field of swede turnips in the North of England. This outbreak was studied by Potter,‡ who isolated a *Pseudomonas* with which he was able to infect turnips. Potter later stated§ that the organism "proved to be identical with *P. campestris*," but details of the proof were not given. Johnson and Adams‖ also isolated from diseased swedes in Ireland, a *Pseudomonas* which

* In a recent classification of bacteria proposed by American bacteriologists, this organism is referred to as *Phytomonas campestris*.

† Jour. Bd. of Agric. IX. 1902. p. 25.

‡ Jour. Bd. of Agric. IX. 1902. p. 28.

§ Jour. Bd. of Agric. X. 1903. p. 314.

‖ Econ. Proc. Roy. Dublin Soc. II. 1910. p. 1.

FIG. 1.

Leaf of Savoy naturally infected with Black Rot.

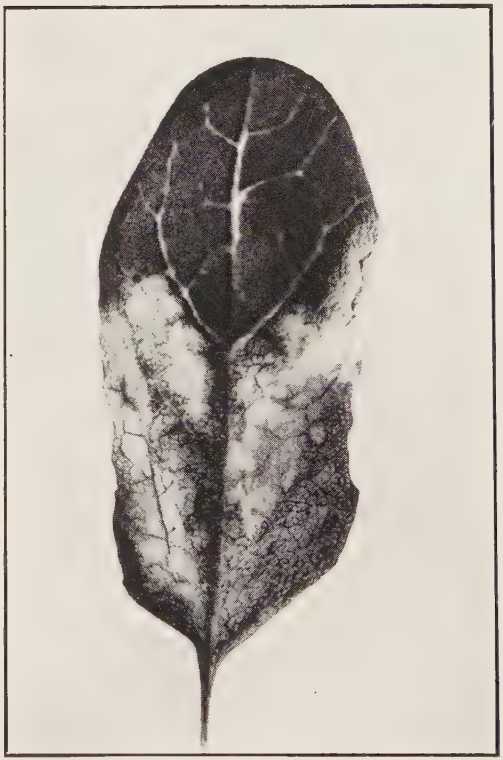


FIG. 2.

Leaf of Savoy infected with Black Rot as a result of inoculation with a pure culture of *Pseudomonas campestris*.

they stated to be *P. campestris*, although their description was not sufficient for exact identification.

Dr. S. G. Paine, of the Imperial College of Science, South Kensington, informs us that he has isolated the " Black Rot " organism from seakale, broccoli and turnip, and one of Dr. Paine's strains has been studied by Mehta, who shows that although different in one or two features, it closely resembles the American organism in its physiological reactions, but no inoculations on living plants are mentioned.

When therefore the disease appeared at East Malling we thought it desirable to make a brief study of it with the object of comparing the organism, in its physiology and parasitism, with *Pseudomonas campestris*. A yellow bacterium, with a single polar flagellum, was isolated from a diseased broccoli, and this was compared with a type culture of *P. campestris*, that was kindly sent to us by Dr. Erwin F. Smith, of the United States Department of Agriculture, at Washington. Simultaneous physiological tests were carried out with the two strains. They were found to be indistinguishable in those features which are considered to be " salient characters " for the identification of bacteria, and the East Malling strain was therefore found to have the same " group number " as the type organism, viz., 211.3332513.* This group number is the same as that determined for the Black Rot organism by Smith and by Harding.†

Using pure cultures of the East Malling strain, inoculations were made on broccoli plants by inserting the organism into the leaf-tissues through punctures made with a sterilised needle. At a number of the inoculated spots the typical symptoms of the disease appeared as a general yellow discoloration accompanied by a blackening of the veins (see Fig. 2). Spraying leaves of young broccoli plants with a suspension of the bacteria in water was less successful, but on one leaf the typical marginal infection appeared. From one of the inoculated leaves which became infected the organism was re-isolated and the physiological tests again applied with the same results as in the previous tests with the original isolation.

Although the disease appears to be generally not so virulent in this country as in America it is probably fairly well distributed in the British Isles and at times causes serious loss. The early records of the disease in the British Isles are referred to above. The most recent reference to its distribution in England is contained in the report issued by the Ministry of Agriculture on " Fungus and Allied Diseases of Crops, 1922-24," in which Black-Rot is reported as being

* Each figure in this number refers to a particular character or reaction, and the description of an organism may be found by comparing its " group number" with a chart prepared by the Society of American Bacteriologists. The strain studied by Mehta differs from ours and Dr. Smith's type strain in not liquefying gelatine, and in reducing nitrates without liberation of gas.

† See " Bacteria in Relation to Plant Diseases," by E. F. Smith, Vol. II. 1911, p. 328.

found in Sussex, Yorkshire, Essex, Middlesex and Lincolnshire ; in one instance 75 per cent. loss in the crop was recorded.

As the disease is probably new to many readers of this report a brief reference here to measures of control may not be out of place. Professor Potter in his description of the outbreak on which he made observations offered the following recommendations, " The attack being confined to the Cruciferæ, crops belonging to this order should not follow each other for several years, the decaying plants ought not to be given to stock, nor should the manure from animals fed on these plants be used for crops liable to the infection. A serious outbreak of brown rot has been traced to infected manure. If also rotting plants are allowed to remain in the field the germs infect the soil and are ready to infest the succeeding crop."

It has been found that the organism is very resistant to desiccation and it is believed that it is sometimes carried on the seeds and so causes infection of the crop raised from such contaminated seed. Seedsmen then should not collect seed from an infected crop.

# NOTES ON PLANT DISEASES IN 1927.

By H. WORMALD.

## Damage caused by Non-Parasitic Agents.

Of injuries resulting from unusual weather conditions the most striking were those caused by late frosts towards the end of April, when fruit blossom received a severe check. At the time it was generally thought that irretrievable damage was caused to some varieties of apples, and although the loss was severe in some cases, in others fair crops were obtained. Strawberries, too, suffered and not only was " Black-eye " observed in cultivated varieties, but it was seen also on wild strawberry plants in the woods. The young shoots and leaves of early varieties of walnut, which are being grown for trial at this Research Station, were killed by the frost and a similar result was observed in the case of chestnut shoots in copses in the neighbourhood of this Station.

A russetting of young apples (becoming conspicuous when they were from a half to one inch in diameter), particularly round the " eye " of Bramley's Seedling apples, was noticed in June, and enquiries were received from various localities as to its cause. The normal smooth skin was replaced by a rough corky layer which resulted in obvious disfigurement. This damage again was attributed to the late frosts as was also a blistering and puckering of the leaves in some varieties. This russetting of the fruit persisted through the season and apparently did not impair the keeping qualities. A number of Bramley's Seedling apples, taken from the store in February (1928) had about one-third of the surface round the " eye " russetted in this way, but otherwise they were quite sound.

During June young apples (variety Cox's Orange Pippin) were received which were badly cracked. This damage was attributed to the effect of heavy rains following a period of drought.

Towards the end of May it was noticed that on the Norfolk Beauty apple trees on the Station many of the branches had dead tips. In some cases the terminal portion was quite dead and bore fungal fructifications, while below this was another portion which had died recently and bore flower trusses which had withered just as the flowers were opening. A similar condition was also noticed on a neighbouring farm. No organism could be found in the tissues recently killed and culture plates set up to test for the presence of fungi or bacteria gave negative results. At present therefore this damage cannot be traced to the action of a parasitic organism. As the specimens found on this Station were mostly on trees growing on that half of the " Pruning Plot " lacking potash, it is suggested that the condition is an extreme form of " Leaf Scorch," which is now

known to be generally associated with a deficiency of potash in the soil. In July " Leaf Scorch " itself was conspicuous on this plot. Apple leaves showing typical " scorch " were also sent in from Mid-Kent about the same time, the grower writing to say that with him it was found on the varieties Bramley's Seedling, Lord Derby, Worcester Pearmain, Lane's Prince Albert and Beauty of Bath.

One case of " rust " of young cherry shoots (variety Early Rivers) came to my notice. As mentioned in the Report for 1925 Early Rivers is a variety that appears to be particularly liable to " rust." This condition seems to be the same as one known in Germany as " Lohkrankheit," or Tan Disease, presumably from the tan colour of the disorganised cells of the bark which are seen as the outer layers strip off.

An example of the pronounced effect of spray damage was observed on the Spraying Trials plot. Apple trees, of the variety Stirling Castle, which had suffered premature leaf-fall after having been sprayed with lime sulphur in 1925 and 1926, showed definite stunting in 1927 (the sprayed trees being markedly smaller than the unsprayed trees of the same variety and on the same stock) as a result of the check induced by the loss of leaves during the period of growth.

Potato Blight (*Phytophthora infestans*).

Potato Blight which appeared early in June in 1926, was not observed in 1927 in the East Malling district until July 22nd, when it was found in a private garden at East Malling. On July 30th it was seen in allotments and in a garden at Maidstone and was obviously spreading rapidly. Early in August it appeared in patches on the unsprayed plots of British Queen on this Station and during the second week of August it was general in the neighbourhood of East Malling. By the middle of August the difference between the sprayed and the unsprayed plots on the Station was very striking. The following notes taken on August 22nd show the value of Bordeaux mixture (10:6:100) in checking the spread of the disease.

*Control* (unsprayed). All the foliage was blackened and withered; the haulms were upright.

*Sprayed once.* All the younger leaves were blackened, but the older, lower, leaves were mostly green and healthy.

*Sprayed Twice.* These plots looked far better than those sprayed once and were very little worse than those sprayed three times. Many of the apical leaves however were blackened.

*Sprayed Three Times.* The leaves were generally green and healthy though a few showed some infection. The haulms were almost prostrate from the weight of the leaves and so contrasted with the upright haulms (with withered leaves) of the control plots.

Grey Mould (*Botrytis cinerea*).

This disease, which is often prevalent during periods of wet weather, was again found on a number of hosts in 1927. Though it does not as a rule cause any very serious damage, it may, in some cases, become troublesome. As the fungus produces spores freely in wet weather, diseased plants should be regarded as sources of infection and the infected parts should, when practicable, be removed and burnt.

It is frequently a cause of fruit rot, especially of the soft fruits, and during the year it was found associated with rots of peaches, plums, Morello cherries, strawberries, raspberries, loganberries and gooseberries. During November this fungus was found on a number of apples in the store, the varieties on which it was found being Newton Wonder, Orleans Reinette and Laxton's Superb. Later other specimens were found which were completely rotten and containing numerous sclerotia of the fungus.

As shown in previous reports the fungus also attacks other parts of plants. It is known to be the cause of a " Die-back " in gooseberry bushes and a few examples of this disease were found on the Station. It was also found on an unopened medlar flower and on the stalks of raspberry canes, in some of the latter extending from the leaves into the canes. A disease actually killing raspberry canes which appears to be caused by the Grey Mould fungus is referred to on a later page.

Apple and Pear Scab (*Venturia inaequalis* and *V. pirina*).

Many infections by scab at the time of flowering were noticed. In some cases, as last year, scab spots were found on the petals. On April 22nd pear flowers, of the variety Emile d'Heyst, were found infected ; the infection was most conspicuous on the petals, but a little was found on the calyx and on the receptacle (fruitlet). On the same date scab infections were found on the flowers of a young tree, of the apple stock Type VIII, growing in a pot. In this case again the fungus was most evident on the petals, but it was also present on the calyx, receptacle and the flower stalk ; the leaves surrounding the flower clusters were thickly infested.

On May 4th and 5th, observations* were made on the infection of the flowers on a number of varieties of pears on this Station. The infection was mostly on the calyx lobes, but it was also found on the receptacle, the flower stalk, and occasionally the petals, of the following varieties : Emile d'Heyst, Georges Bouchier, Durondeau, Conference, Beurré d'Amanlis, Fondante de Thurriot, Hessle, Nouveau Poiteau, Pitmaston Duchess, Reine des Poires, Chaumontel, Fertility, and Beurré Alexandre Lucas.

* These observations were made by Mr. M. H. Moore.

Such observations show the necessity of applying a spray for scab control before the flowers open. Pre-blossom spraying (at the " pink stage " in apples) should be routine practice in orchards and plantations where scab had been prevalent during the previous season.

During August apples and pears were sent in showing very numerous small spots which proved to be scab. One apple had more than 200 of these small spots on half its surface, while the other half was nearly free from spots ; one typical scab about a quarter of an inch in diameter, was near the centre of the badly infected half. Another apple had over 100 spots over an area measuring $1\frac{1}{2}$ inches by $\frac{3}{4}$ inch, with others scattered over the rest of the surface ; again a typical scab spot about a quarter of an inch in diameter was near the centre of the thickly infected area. Pears (variety Beurré Diel) were received showing similar, very numerous small spots. It would seem from such cases, that primary infection spots on the fruit serve as centres from which other infection spots arise on the same fruit, especially in wet summers such as in 1927.

Shoots of a Red Siberian Crab bearing leaves thickly infected with scab spots were received from Cheshire towards the end of June.

Sooty Blotch of Apples.

A disease which appears to be identical with one caused by a fungus, *Gloeodes pomigena*, in America, was prevalent on apples in this country in autumn. As the common name implies the symptoms of this disease are marks resembling those that might have been made by sooty fingers. Bramley's Seedling was a variety on which it was particularly noticeable. One grower, who brought specimens for identification of the spotting, said the disease on his farm was present on the varieties Bramley's Seedling, Lord Derby, Blenheim Orange, and Northern Greening, while Cox's Orange Pippin also showed a little. In February (1928) apples of the variety Allington Pippin, taken from the store on an East Malling fruit farm showed conspicuous blotching.

Though the disease has been known in this country for years, it is rarely a cause for serious complaint, and 1927 appears to have been a year particularly favourable for it. This disease together with scab, was often seen during the autumn and winter on fruit exposed for sale in fruiterers' windows.

Apple Mildew (*Podosphæra leucotricha*).

Two features of interest with regard to Apple Mildew were observed during the season. Early in June shoots of Bramley's Seedling received from North Kent bore leaves which were curled and blistered with aphis attack ; the curled leaves were nearly all infected with mildew, and the fungus was almost confined to such leaves on the specimens examined.

Apple Mildew is usually not common on the actual fruit, but in July a number of Lane's Prince Albert trees were seen on which many of the fruit

showed mildew; on some trees at least fifty per cent. of the apples were infected.

Quince and Pear Leaf-spot (*Fabræa maculata*).

Quince leaf-spot was again present on the type trees in the "Museum Plot" on this Station. In spite of an early spraying with Bordeaux mixture the disease spread and in September even certain varieties which usually show little spotting had nearly all their leaves infected, while the more susceptible varieties had, by this time, lost a considerable number of their leaves by reason of the severe infection.

Towards the end of September leaf-spot was present on the stool rows of quinces, but mostly on the lower leaves only; on one variety (Type C) however, some stools showed pronounced leaf-fall.

Leaf-spot of pears caused by this fungus is not common in this country. An instance of its spreading from quince trees to pear trees was observed on this Station. A number of Conference pear trees were growing in pots in close proximity to young quince trees which were infected with this disease. The leaves on those branches of the pear trees which were in contact with the quinces became spotted, while those further away though only separated by a few feet, were quite clean. The difference could be seen even on the same tree, the leaves on the side next to the quinces being conspicuously spotted while those on the opposite side were free or almost free from spots. The restricted spread of the disease on the pear trees was correlated with the absence of fungal fructifications from the spots on the pear leaves, although on the quince spots fructifications with numerous spores were produced.

Brown Rot Diseases.

Blossom wilts caused by *Sclerotinia cinerea* were far less common in 1927 than during the previous season. That this fungus may sometimes infect unopened flower buds of Morello cherries was pointed out in the Report for 1925. In 1927 two instances of the infection of unopened flowers of sweet cherries were noted; one case was on a young tree on this Station, while the other specimens were received from a fruit farm in the Weald.

Fruit rot caused by *Sclerotinia fructigena* was again common from the beginning of July onwards. As during the previous year, this fungus was found not only on apples and pears, but it was the chief cause of rot in various varieties of plums. *S. cinerea*, the other common brown rot fungus of this country, was only occasionally found on rotting plums in 1927.

The so-called "Black-Rot" of apples, caused by *S. fructigena* (the common brown rot fungus of apples) was found in a number of varieties of stored apples during October and November. The varieties showing black rot were Lane's

Prince Albert, Prince Bismarck, Laxton's Superb, Rival, Newton Wonder, and Bramley's Seedling. Apples with this type of infection soon turn black and bear relatively few (sometimes none) fungal fructifications.

*S. fructigena* passes the winter almost solely on the mummified fruit infected during the summer and left on the trees until the following season. In order to check these outbreaks of fruit rot it is essential therefore that growers should see that no " mummies " are left on the trees through the winter.

### Gooseberry Diseases.

American Gooseberry Mildew (*Sphærotheca mors-uvae*) was first observed (1927) on May 23rd, and towards the end of that month and during June it was spreading in a number of places as shown by the enquiries received respecting control measures.

Only one case of European Gooseberry Mildew (*Microsphæra grossulariæ*) came to my notice during the season.

Leaf Spot caused by *Pseudopeziza ribis*, was less severe in 1927 than in the previous year, a result probably of the drier spring. Bushes, which in 1926 had shown severe spotting with pronounced premature leaf-fall, were examined during the first week of July, 1927, but only a few spotted leaves could be found and as yet there was no leaf-fall.

Gooseberry Cluster Cup (*Puccinia Pringsheimiana*) was found on a few leaves on this Station early in May, and a few weeks later specimens showing the disease on leaves and berries were received from Sussex. In neither case was the attack serious. As one stage in the life-history of this fungus is passed on another host-plant (species of sedge), this disease is rarely troublesome in well-cultivated plantations.

### Black Currant Diseases.

American Gooseberry Mildew on black currant leaves was sent in from Kent, Worcestershire and Hampshire. One outbreak was on two year old bushes of the Baldwin variety. As noted in 1925, only the terminal leaves on the shoots were infected ; the Oidium stage was present on both sides of the leaves and the leaves themselves were distorted in consequence.

Leaf Spot (*Pseudopeziza ribis*) was again serious on Baldwin black currant bushes. Specimens brought in from two localities in Kent in July showed very pronounced spotting, many of the leaves having a withered appearance in consequence. Later in the season premature defoliation in this variety was widespread as a result of early infection with this disease. One grower in West Kent wrote, about the middle of September, " I have had a very bad attack of *Pseudopeziza* in the Baldwin black currants. It took the leaves off some of the trees before we got the fruit picked. The result was small fruit inclined to

shrivel and we found the trees that were attacked picked one pound less than the healthy. Now there is hardly a leaf left on the three acres. The strange thing was it did not attack other varieties growing alongside the Baldwins till now."

Raspberry and Loganberry Cane Spot (*Plectodiscella veneta*).

Of the diseases of raspberries mentioned in previous reports Cane Spot (*Anthracnose*) appears to be the most generally distributed and a number of enquiries have been received concerning control measures against this disease, not only on raspberries but also on loganberries. Experiments carried out on the Station have shown that spraying with either Bordeaux mixture or lime sulphur reduces the spotting and increases the crop.*

Spur Blight of Raspberries (*Didymella applanata*).

This disease, although it does not usually kill the canes, may destroy or weaken the fruiting laterals. Two cases where infection by this fungus was conspicuous were noted, one in a garden at Maidstone, the other in a commercial plantation at East Malling. In the latter the variety affected was Reader's Perfection, a variety which would seem therefore to be particularly susceptible.

Grey Mould on Raspberry Canes.

Dead raspberry canes (variety Lloyd George), on which was the Grey Mould fungus (*Botrytis cinerea*) under conditions suggesting that this organism was the cause of their death, were received from a grower in December. The conidial fructifications and also sclerotia of the fungus were present on the canes, and this fungus, which is known to assume a parasitic habit on various hosts when conditions are suitable, is probably the cause of the damage, though the frequent rainy periods during summer and autumn were conducive in aiding the fungus.

Downy Mildew of Hops (*Pseudoperonospora humuli*).

During 1927 Downy Mildew was widespread not only in Kent but also in other hop-growing counties. In spring the " spike " stage was common. During the summer " wild " hops bearing leaves spotted with this fungus were found in six different spots between East Malling and Maidstone. In one instance the infected wild plants were allowed to scramble over bushes within four yards of the side of a large hop garden ; no definite evidence of infection was seen in the garden itself except on a plant on the edge and very close to the infected wild hops. During August and September hop cones and leaves were brought or sent in from many localities and in some instances the crops were severely damaged. In some cases the hops had to be picked early because of the infection, and one grower left eight acres of Bramlings unpicked owing to Downy Mildew.

* See Annual Report Part I. (General) for 1927.

Three acres of Tutshams on this Station were only slightly attacked and this only towards the end of the picking. Among the Tutshams were several "rogues" and these were very seriously infected, in fact too bad to be picked. This shows the importance, from a pathological standpoint, of growing varieties true to type.

Pea Mildew (*Erysiphe polygoni*).

Observations on plots of Gradus peas grown on this Station indicate that Pea Mildew may, during a wet season such as 1927, cause appreciable damage to the crop.

Mr. H. C. Chapelow supplied the data given in the accompanying table :—

| Date of Sowing. | Mildew first observed. | Mildew Severe. | Estimated damage to crop. |
|---|---|---|---|
| April 4 | June 18 | June 21 | 50 per cent. |
| April 19 | June 18 | June 21 | 50 per cent. |
| May 3 | June 21 | July 9 | 60 per cent. |

A Rhubarb Rot.

Two cases of rot in rhubarb, associated with the presence of a species of *Verticillium* in the diseased parts, were noted. This disease is receiving attention in order that the fungus may be compared with species of *Verticillium* which have been found associated with wilt diseases in raspberries and hops.

Other fungous diseases which came under notice during the year were :—

Witches' Broom of Cherry (*Exoascus cerasi*).

Plum Scab (*Cladosporium carpophilum*) on Yellow Egg Plums from Worcestershire.

Tomato Leaf Mould (*Cladosporium fulvum*).

Downy Mildew of Parsnip (*Plasmopara nivea*) in an allotment at Maidstone.

Downy Mildew of Onion (*Peronospora Schleideni*).

Powdery Scab of Potato (*Spongospora subterranea*).

Mint Rust (*Puccinia menthae*).

Rhubarb Rust (*Puccinia phragmitis*).

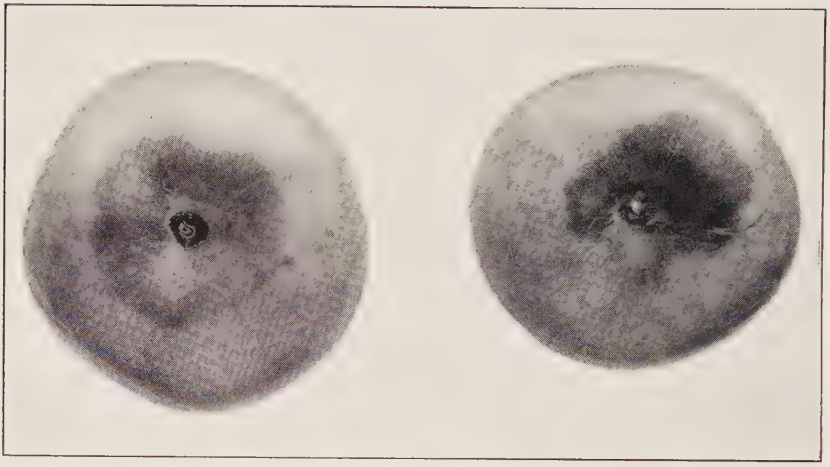


FIG. 1.

Apples three days after picking: infection has set in where the apples were pulled from the stalks.

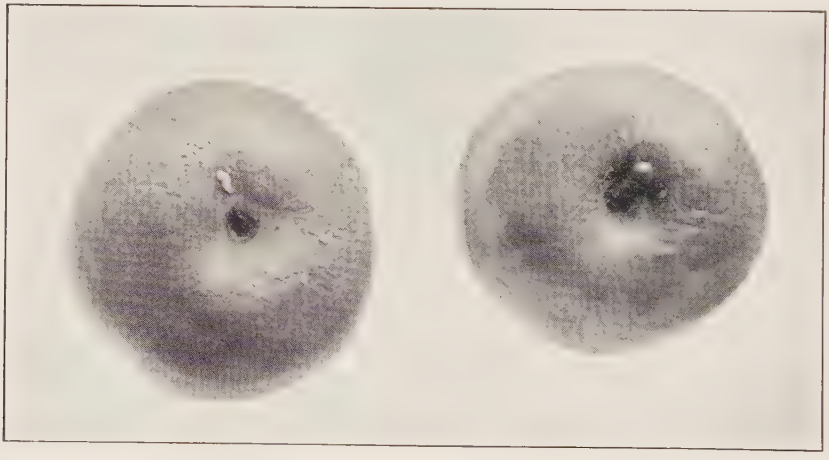


FIG. 2.

The same apples two days later. The rot has extended and the apple on the left bears fructifications of *Sclerotinia fructigena*.

# BROWN ROT OF APPLES: THE NEED FOR CAREFUL PICKING AND SORTING.*

By H. WORMALD.

In recent years, the brown rot disease of fruit, caused by *Sclerotinia fructigena*, has been very prevalent. The disease was particularly severe in 1926, and it was not only common on apples and pears, the usual hosts of this fungus, but considerable loss in the plum crop resulted from infection by the same parasite.†

So far as is known, primary infection of the fruit by *Sclerotinia fructigena* takes place only through wounds, such as those caused by biting insects, but when one apple of a cluster becomes infected, the disease can extend from that apple to those touching it, across the points of contact. The fruit may be infected when young and growing, and also at maturity, while infection may also take place at the time of picking or during the subsequent handling. The disease is the most common cause of loss in apples during the early stages of storage, and the so-called " black rot " of stored apples is caused by the same fungus. As mechanical injury renders the fruit so liable to infection, it is obvious that, especially in years of epidemic infestations, care must be taken not to cause unnecessary injury when the fruit is picked and afterwards when it is graded and packed or stored.

One form of injury may occur at the time of picking by removing the fruit from its stalk instead of picking it with the stalk attached. That injury of this kind may soon lead to loss in the crop is shown by observations made at East Malling in the autumn of 1926.

Early in September, as the apples were being picked and graded for packing and marketing, it was noticed that fruit, apparently quite sound when received from the pickers, showed very pronounced brown rot within two or three days. On investigation it was found that in nearly every instance the rot started at the stalk end, and this condition only appeared on those apples which had been pulled away from the stalk when picked. Observations were made on a batch of apples which had been picked three days previously, and already a number of those without stalks showed the typical brown rot, the discoloration in some cases extending for half an inch or more from the stalk end wound.

The variety in which this type of injury was observed was " James Grieve," which is not only very susceptible to brown rot infection of the fruit, but, being

* This article appeared in the Journal of the Ministry of Agriculture, Vol. XXXIV, No. 6, Sept., 1927, pp. 552-554, and is reprinted here by permission of the Ministry and H.M. Stationery Office.

† A closely related fungus, *Sclerotinia cinerea*, also causes brown rot of plums and cherries; in addition to causing fruit rot, it infects the flowers and so produces blossom-wilt.

a soft-wooded variety, the rot often extends from the fruit into the spurs and also into the branches to form cankers.

To obtain some idea of the rate at which rot progresses in fruit infected in this way, apples showing rot starting at the stalk end were selected ; two of them were photographed at this stage and are shown in Fig. 1. The margin of the brown area in each case was then marked with ink. The apples were placed on a bench in an unheated laboratory, the temperature of which was approximmately that of the packing shed.

On the following day it was found that the rot had extended 7 to 16 mm. (on the average about $\frac{1}{2}$ in.) beyond the marked line within the twenty-four hours. During the next twenty-four hours the rot proceeded at about the same rate, so that nearly half the surface of each apple was brown, and a few yellowish spore-bearing tufts, the fructifications typical of the fungus, were appearing at this stage (see Fig. 2). A few days later the apples were completely brown, and numerous fructifications were present. It is obvious that the apples had become infected soon after they were picked, and that the fungus had entered through the wound caused by removing the fruit from the stalk.

It is apparent, also, that had these apples been sent to market, when they already showed evidence of infection, they would have been unsaleable soon after their arrival. However carefully apples are picked, a certain number will be pulled away with damaged strigs. During grading these should be set aside with the bruised fruit for immediate use. Such fruit should not be stored. Slight injuries in themselves are not necessarily very harmful, but since they serve as ports of entry for certain parasites, such as the one under consideration, care in picking, grading and packing is essential for successful storing and marketing of fruit. Since it is impossible to eliminate mechanical injuries altogether, especially when large quantities of fruit have to be handled, the grower should endeavour to reduce the chances of infection to a minimum by removing as far as possible all sources of infection. In certain seasons it is not uncommon, at the time of picking, to see the ground under apple and pear trees strewn with fruit infected with brown rot and bearing myriads of spores which blow about and cause further infection. The collecting of such fruit and rendering them innocuous by burning or burying is possible in a garden or small plantation, but is hardly a practical proposition on large fruit farms.

The grower, however, should realise that rotting fruits, whether on the tree or on the ground, are a source of danger, and when it is at all practicable they should be destroyed. He is reminded, too, that apples infected with brown rot frequently remain on the tree through the winter. These " mummies," if left on the trees, produce, in the following spring, another crop of spores which serve to start infection in the young fruit. It is therefore sound practice to remove, during the winter, any withered apples that may be found on the trees.

# BACTERIAL DISEASES OF STONE-FRUIT TREES IN BRITAIN.

## I. PRELIMINARY NOTE ON BACTERIOSIS IN PLUM AND CHERRY TREES.

By H. WORMALD.

The object of the present note is to call attention to the fact, recently established by experiments carried out at the East Malling Research Station, that there are certain diseases of stone-fruit trees (*Prunus* spp.) in Britain which are the result of infection by bacteria. The investigation of these diseases has not yet proceeded far enough for a full account of the symptoms and descriptions of the causal organisms to be published, but it has been thought desirable to describe briefly the chief symptoms of bacteriosis in plum and cherry trees in order that growers, and others interested in these diseases, may be able to recognise them. More detailed accounts of the various diseases will be given in later articles when further information has been gained respecting the physiology of the organisms in pure cultures, and their mode of parasitism. Meanwhile the knowledge that these particular diseases are caused by parasitic bacteria will enable growers to take precautionary measures against the dissemination of the organisms causing them.

In recent Reports from the East Malling Research Station the present writer has pointed out that the constant association of bacteria with a number of diseases of plum and cherry trees suggests that species of these organisms are the direct cause of the damage. Cultural and inoculation studies carried out on that assumption have offered confirmatory evidence of the parasitic nature of these organisms. It has also been ascertained that there are at least two types of bacteria (probably distinct species) concerned in these diseases, but as certain similar disease symptoms can be produced by either of the two organisms the latter cannot always be readily distinguished from each other by their effect on the host plants.

Bacteriosis of plum and cherry trees has been studied at East Malling in relation to three diseases, viz., (1) Bacterial Shoot Wilt of Plum Trees, (2) Leaf Spot and Gummosis of Cherry Trees, and (3) Bacterial Canker and Leaf Spot of Plum and Cherry Trees. The organisms causing the diseases mentioned under (1) and (2) show great similarity in culture and are probably to be referred to the same species. The organism isolated from stem cankers shows certain cultural differences from that causing Shoot Wilt and may prove to be a distinct species.

(1) Bacterial Shoot Wilt of Plum Trees.

This disease appears as a wilting of the young current year's shoots of plum trees. It bears a general resemblance to the Wither-tip disease caused by the brown-rot fungus *Sclerotinia cinerea*, but it may be distinguished from the latter by the fact that the blackened lesions which produce the wilting are more elongated, frequently extending for several inches along one side only. When however the shoot eventually becomes girdled, that portion of it terminal to the lesion becomes flaccid and wilts. When a particle of tissue from one of the blackened lesions is teased out, and examined microscopically, masses of bacteria are seen to ooze out.

It has been observed only during periods of wet weather and on young trees which have been induced to produce vigorous (but rather sappy) shoots, and these appear to be the conditions necessary for the disease to become serious. Inoculations on young green shoots, with cultures of a bacterium isolated from a naturally infected shoot, have given marked positive results only on sappy shoots growing under moist conditions.

Artificial inoculations into older woody branches have given positive results in some cases and it was at first thought that the shoot-wilt organism might be the cause of the more serious Bacterial Canker. As already remarked, however, there are now reasons for believing that the two diseases are not caused by the same organism.

(2) Bacterial Leaf Spot and Gummosis of Cherry Trees.

The copious gumming often shown by cherry trees is not yet thoroughly understood though various possible explanations have been put forward to account for it. That it is, in some cases, associated with the presence of bacteria in the lesions has been observed by a number of workers, notably by Brzezinski (4) and by Aderhold and Ruhland (1). The latter found that an organism, to which they gave the name *Bacillus spongiosus* not only caused gummosis but actually killed young cherry trees. Griffin (6) has also studied a disease, associated with gumming, on cherry trees in America and found it to be caused by an organism which he named *Pseudomonas cerasi*. Barss (2) observed that this gummosis of cherry trees was often accompanied by a leaf-spot disease.

The present writer has also found gummosis of cherry trees accompanied by bacterial leaf spot, under conditions which suggested that the two symptoms are a result of infection by one and the same organism. Bacteria which have given similar reactions in preliminary cultural tests have been isolated from leaf spots and also from a gummy lesion on a branch. An organism which has been isolated from a leaf spot has been used for inoculations on opening buds and on branches. The inoculations on the buds in some cases killed the buds outright, while in others the buds grew out and the leaves showed the typical spotting.

The inoculations on the branches were made by inserting a suspension (in sterile water) of the bacterial slime, from an agar culture, in cuts made through the bark as far as the wood ; these gave rise to elongated lesions which exuded copious gum, while the control wounds, to which sterile water only was applied, healed normally without gumming, or in some cases with only a trace of gum. The experiments show therefore that in this country gumming of cherry trees is, in some cases at any rate, to be attributed to bacterial infection.

(3) Bacterial Canker and Leaf Spot of Plum and Cherry Trees.

Fruit growers in this country have at times suffered severe losses from the dying out of trees in plantations of plum and cherry trees. The disease is, as a rule, most severe among young trees recently planted up, although frequently older, well established trees, are either destroyed, or they lose one or more branches. This disease has generally been referred to as " Die-back." Sooner or later fungi usually appear on the stems and branches of such trees and various fungi have been suggested from time to time, as the cause of die-back, although convincing proof, that they are the primary cause of the trouble in plums and cherries, is lacking. Miss Cayley (5) however, offered evidence that a fungus, *Diaporthe perniciosa*, which is frequently found on plum trees affected with die-back, was able to produce infection when inoculated into young peach shoots, and this fungus has lately been generally accepted as the cause of die-back in stone-fruit trees. It has more recently been suggested by Briton-Jones (3) that *D. perniciosa* is a weak parasite, attacking only trees which have become unhealthy from other causes, and that the conditions conducive to the incidence of die-back are obtained when trees are planted up in soil which is detrimental to the roots, such as would obtain in a water-logged soil, or in a soil with insufficient moisture.

Observations at East Malling and elsewhere suggested, however, that these explanations were not of general application, at least in the south-east of England, that the so-called " Die-back " was in many cases caused by a definite parasite, and that this parasite was a bacterium. One of the plum variety trial plots on the Research Station has lost a considerable number of trees from so-called " Die-back." This plot therefore presented an opportunity for a study of the disease.* It was soon obvious that neither unsuitable soil conditions nor the " weak " parasitism of a fungus was sufficient explanation of the losses incurred. The trees were growing in soil considered to be quite suitable for the cultivation of plum trees, and the fact that the trees made excellent development up to the time of the onset of die-back, and also that trees of a number of varieties are actually still flourishing on that particular plot, provided ample proof

* For the distribution of " Die-back " on this plot, see the Annual Report of this station for 1925, II. Supplement, p. 33, March, 1927.

that the soil was not at fault, while the drastic effect that the disease had on the trees was not compatible with the idea of the action of a *weak* parasite. Thus trees which had made excellent growth during the course of one season showed the first obvious signs of disease the next spring and the foliage withered completely during the course of the summer. Moreover the fact that such trees almost invariably had healthy and well-developed root systems when dug up showed that the seat of the damage was above ground and not in the soil.

The symptoms of this disease, as observed on the East Malling plots are : (1) restricted development of young green shoots, (2) the yellowish colour of the leaves which becomes more pronounced as the season advances, followed, sooner or later by (3) the withering of the foliage. These conspicuous signs of disease, when general over the whole tree, are accompanied by areas of discoloured bark on the stem. These infected areas are not at first obvious, but when the tree resumes growth in spring they appear sunken owing to the increase in thickness of those parts of the stem still healthy. As infection extends more rapidly in a longitudinal direction on the stem than transversely, the borders of the infected regions are often marked by longitudinal ridges. On cutting across one of these ridges with a knife the bark on one side will be found to be green and healthy, on the other dark brown. Microscopic examination of the diseased areas found on the stems of trees with these symptoms almost invariably showed the presence of masses of bacteria at the upper and lower limits of the lesions, thus suggesting bacteria as the cause of the damage.

Working on this assumption attempts were made to isolate bacteria from the stems. In the spring of 1926 a bacterium, culturally different from the organisms associated with the two diseases above mentioned, was isolated from several stem lesions. Using cultures of this organism inoculations were made in the autumn of the same year on stems of young plum trees and on branches of older trees. The effect was not seen until the spring of 1927 when the inoculated trees or branches showed symptoms of the disease. These experiments will be described in detail in a later communication. Reference, however, must be made to the results obtained in one experiment in which twenty young plum trees were used. Ten of the trees were inoculated with a suspension from a culture of the organism which was placed in cuts in the bark, the other trees, alternating with the former, being used as controls ; the latter were similarly wounded but sterile water only was placed in the cuts. Each tree was wounded at one place only. The control trees remained healthy throughout the year, the wounds healing normally and becoming covered with callus. On the inoculated trees infection developed from the points of inoculation, producing diseased areas similar to those on stems of naturally infected trees ; in each case the stem became girdled and that part of the tree above the canker died during the course of the spring and summer of 1927.

On the plum trial plot referred to above, the leaves of many trees which were otherwise healthy showed bacterial spotting and "shot-holes." An organism was isolated from such spots which bore a close resemblance in culture to that obtained from the stem cankers, and inoculations on plum stems and branches, using the leaf spot organism as inoculum, gave positive results, bark cankers appearing in every case, followed in some instances by the death of the parts distal to the infected areas. Similar results were obtained with isolations from spots found on the fruit and on the young shoots, inoculations on branches again giving positive results.

Attempts to isolate the organism from cankers late in the season, when the external symptoms of disease become pronounced, have been unsuccessful, and this is correlated with the fact that the cankers cease to increase in size during the summer, thus showing that the bacteria either become inactive or, what is more probable, since isolation tests fail, that they actually die out. Meanwhile however, leaves become infected. This infection of the leaves is sometimes considerable and the riddled appearance of the foliage, as a result of the falling out of the tissues of the infected spots is sometimes a very conspicuous feature. It would appear that the organism is conveyed to the leaves from the cankers, but how this is brought about has not yet been determined.

On the East Malling plots the cankers have been mostly on the main stem, so that the resulting effect, the yellowing and final withering of the foliage, was seen on all the branches. In most of these cases the lower part of the stem and the roots remained alive and shoots grew out from the lower part of the scion stem or from the stock. On some trees individual branches became infected.

As the term "Die-back" has been used for the dying out of trees from causes other than those described in this paper, and since the expression is an unsuitable one for the many cases where trees die as a whole and not backwards from the tips, it is proposed to name the disease "Bacterial Canker."

Although the disease has been studied chiefly with regard to its occurrence on plum trees, bacterial canker also attacks cherry trees. An organism which appears to be identical with that of the plum canker has been isolated from a cherry stem; this strain has been used in inoculations on the stems of young cherry trees and, although the results have not been so striking as in the experiments with plum strains, they proved that the organism was able to produce bacterial canker.

Growers and raisers of fruit trees who are suffering loss from diseases similar to those above described are asked to send specimens, together with particulars of the outbreaks, to the writer, in order that they may be compared, as to the symptoms and the cause of the damage, with affected trees that have been examined at East Malling. In this way information can be obtained respecting the distribution of these diseases and the extent of the damage caused by them.

The observations recorded in this paper have been made almost solely on trees at East Malling. It is known, however, that similar symptoms have been observed elsewhere and it is believed that the same diseases (particularly with reference to bacterial canker) are prevalent in other parts of the country. Specimens of plum trees showing the typical symptoms of bacterial canker have been received from various districts in Kent and from the Evesham and the Cambridge districts but they arrived too late in the season for successful cultural tests. Die-back specimens should be sent on as soon as the symptoms recorded above (retarded growth and yellowing of the foliage) are recognised. If these symptoms are general over the whole tree the trunk should be sent.

Experiments are in progress to ascertain whether field control measures are likely to be effective. In the meantime growers are advised to practise orchard hygiene by removing and burning infected shoots (in the shoot-wilt disease), branches and trees, and this should be done as soon as the diseases are recognised. With regard to bacterial canker, trees showing obvious yellowing of the leaves, with retarded growth, should be examined for canker on the stem. If canker is present it is good evidence that the trees are infected with disease of the type here described. Such trees are not known to recover and therefore should be removed on the earliest possible opportunity. These measures do not apply to trees affected with leaf-spot only, except perhaps in the case of very young nursery trees seriously infected, since trees which show bacterial leaf-spot do not necessarily become infected with canker on the stem.

The correlation between leaf-spot and bacterial canker has not yet been followed closely. One case, however, has come under the writer's notice where young plum trees on a nursery plot showed conspicuous spotting of the leaves in the summer of 1926, and during the following season a large proportion of the trees died from bacterial cankers on the stem. The possibility that this association may not be mere coincidence is suggested by the fact, already referred to, that an organism isolated from a leaf-spot was able to induce canker of the stem.

## Summary.

Descriptions are given of certain bacterial diseases of plum and cherry trees in this country. Experiments have shown that bacteria may cause :—

(1) Shoot Wilt of plum trees.

(2) Gummosis and Leaf Spot in cherry trees.

(3) Bacterial Canker in plum and cherry trees.

The relation between the so-called " Die-back " of stone-fruit trees, and the disease here described as " Bacterial Canker " is briefly discussed.

FIG. 1.

Plum Tree with Bacterial Canker on the stem, withering when in full leaf.

FIG. 2.

Plum leaf showing Bacterial Leaf Spot and "Shot-hole."

FIG. 3.
On the left a Victoria Plum Tree infected with Bacterial Canker; on the right a healthy tree for comparison. May 5th, 1927.

FIG. 4.
The same trees as shown in Fig. 3, photographed on October 3rd, 1927.

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# THE PATHOLOGY OF THE RASPBERRY: A SUMMARY OF RESULTS OF RECENT RESEARCH AT EAST MALLING.*

By R. V. HARRIS.

INTROUCTION.

Research during the period mentioned was mainly concentrated on the four following diseases :—

A. Blue Stripe Wilt. (*Verticillium Dahliae* Kleb.)

B. Cane Spot. (*Plectodiscella veneta* (Speg.) Burk.)

C. Mosaic.

D. Spur Blight. (*Didymella applanata* (Niessl.) Sacc.)

In the great majority of diseased stools examined at East Malling and elsewhere, symptoms of one or more of the above diseases have been apparent.

A summary of the results obtained will be given for each of the above diseases, with particular reference to points suggesting control measures applicable in the field, and therefore of importance from the grower's point of view.

During the three years, a considerable amount of advisory work has been carried out both by visits paid to growers' plantations, and by correspondence and the examination of diseased stools submitted by growers. About 100 advisory letters have been written in answer to enquiries and some 20 visits paid to affected plantations in different parts of the country. Two tours of the Scottish Raspberry growing districts were also made.

Considerable data have thus been collected on the distribution of the diseases and also supplementary data on the relative susceptibility of varieties to the diseases.

## A. THE BLUE STRIPE WILT.

### 1. *Cause.*

A species of *Verticillium* found to be constantly associated with the diseased canes was isolated and was proved by inoculation experiments to be the cause of the disease. An examination of the morphology of this fungus in artificial culture indicates that it answers closely to the species *Verticillium Dahliae*, Kleb. as defined by Miss Van der Meer.†

* This research, extending from October, 1924, to October, 1927, was carried out under a special grant from the Ministry of Agriculture.

† "Verticillium-Wilt of Herbaceous and Woody Plants." Med. Landbouwhoogesch. Wageningen. Dl. 28. 1925.

2. *Symptoms.*

The seasonal cycle of the fungus and the symptoms of the disease have been determined and a description published.*

3. *Mode of Spread.*

The fact that no production of air born spores has been observed on the aerial parts of stools in the field, and that the infection of canes always takes place from the underground root-stem system, suggests that the initial infection of stools takes place in the underground root-stem system from the soil. The only reproductive bodies found on the canes are the resting bodies or microsclerotia, which are commonly found in the bark tissues of dead canes.

4. *Control.*

Taking these facts into consideration it was thought advisable at the commencement of the investigation and until more was known concerning the distribution and spread of the fungus in the soil, to advise growers to propagate only from stools free from disease symptoms, and to rogue, rigorously, all diseased stools in affected plantations, removing, also, and burning, all dead cane found in the course of the winter pruning of stools.

Recent work on the disease, however, although it confirms the necessity of eliminating seriously diseased stools from the plantation, tends to indicate that in selecting stools for propagation, great emphasis need not be placed on the discarding of stools which have shown slight symptoms of wilt in the previous season. The results of artificial infection experiments, and experiments in the dissemination of the disease by vegetative propagation, show that the parasitism of individual canes (as distinct from the underground root-stem system) is brought about by a very specialised set of external conditions, e.g., cultural, seasonal, etc. Thus a stool known to be infected with the fungus and showing slight symptoms of wilt may, when planted out elsewhere, grow away without any sign of disease. Conversely, canes apparently healthy may, when transplanted, develop disease symptoms during the first season. Also stools showing disease one year may be normal the next year. It is quite clear from the foregoing that future work must be concentrated on determining (1) the mode of, and conditions determining, the initial infection of stools known to be fungus free to start with, and, (2) given an infected stool, the critical conditions inducing subsequent recovery.

5. *Varietal Susceptibility.*—The survey of varieties from the point of view of the incidence of this disease indicates that in a given locality certain varieties are more susceptible than others. Certain varieties, however, appear to be very susceptible in the majority of localities in which they have been examined.

* Journ. of Pomol. and Hort. Science, Vol. IV., Nos. 3 and 4.

Among such generally susceptible varieties the following might be mentioned :—

Bath's Perfection.
Red Antwerp B.
Prior's Prolific.

In any locality in which the disease is at all prevalent it would be advisable to avoid such varieties. All the varieties observed, however, have been seen in one or more localities growing well and free, or practically free from symptoms of the wilt. The important thing therefore in the case of this disease would appear to be the selection by experiment of the right variety for the set of external conditions obtaining in the particular locality, given which, the stools, although they may be initially infected with the fungus, will in all probability grow away quite normally.

Whether, in the case of a badly attacked variety in an established plantation, it is possible to control the disease by treatments modifying the soil conditions, remains to be investigated.

B. Cane Spot.

1. *Cause.*

A fungus was found to be constantly associated with the cane lesions, which both by the morphology of its fructifying stages as seen on the cane, and by the character of its mycelium in artificial culture, resembles closely, if it is not identical with, the fungus causing the Anthracnose disease of species of Rubus in America, i.e. *Plectodiscella veneta* (Speg.) Burk.

2. *Symptoms.*

The seasonal cycle of the fungus has been determined, and the symptoms of the disease in the field recorded and published in a preliminary and popular account of the disease.*

3. *Varietal Susceptibility.*

Records on the incidence of the disease on the trial plots at East Malling, and on plantations in other parts of the country, indicate that differences in relative susceptibility between varieties are very marked. The most susceptible variety recorded up to the present is *Baumforth Seedling B.* The following varieties are also very susceptible—*Semper Fidelis*, *Reader's Perfection* and *Devon.*

4. *Control.*

(*a*) *By Spraying.*—Two field experiments in control by spraying have been carried out on the variety Baumforth B. Both have given satisfactory results

* " Three Raspberry Diseases." Ann. Report, East Malling Research Station. 1925 (1926).

showing that the severity of attack can be considerably reduced by this method of control. For the first trial the washes used were Bordeaux Mixture and Lime Sulphur and data on the effect on the crop show that an approximate increase in crop weight of fifty per cent. was obtained by the use of each of them.*

(*b*) *Other Methods.*—An experiment on the effect of the removal of infected canes during the spring thinning operations was carried out, and indicates that a considerable reduction of the infection of new canes is obtained by cutting out and burning very badly cankered canes.

The ideal control measures against the disease, would, therefore, appear to be a combination of spraying and the removal of badly diseased canes in the spring.

With a view to the cleaning up of an established plantation very seriously infested with the disease, the following somewhat drastic measure was tested. In the early spring the whole of the current season's fruiting cane was cut down as close to the ground as possible and burnt. As a result it was found that the infection of the current year's new cane was practically eliminated. A plantation so freed from the disease should be kept clean by the application of the routine control measures outlined above.

It follows, that in planting up a new plantation of a susceptible variety, using cane which is in all probability infected, it should be possible to check infection by cutting all the cane back as hard as possible, soon after planting, and burning the cane thus cut away.

## C. Raspberry Mosaic.†

### Introduction.

The study of this disease was undertaken as a result of the enquiries of growers concerning the cause and significance of a mottling of the foliage of the stools of some of their varieties. The first stage in the investigation was a periodic survey of the variety trial plots at East Malling with the object of obtaining data on the incidence and symptoms of the disease. As a result, indications were forthcoming (1) that in some varieties a mottling of the foliage was associated with a dwarfing of the cane and a failure in the crop of affected stools, (2) that the disease was not merely seasonal, i.e., it persisted from year to year, and (3) that in certain varieties it appeared to be spreading.

Field experiments were then designed to explore these points further, and particularly to find whether the disease was handed on by vegetative

* A paper giving the strength of washes used, times of application, etc., has been published in the Annual Report, East Malling Research Station. I. General, 1927 (1928).

† The work on Raspberry Mosaic has been carried out in collaboration with Mr. N. Grubb and Mr. A. M. Massee.

propagation, or whether it was not due entirely to the external conditions (e.g., cultivation, fertility of soil, drainage), to which the stool was subject, in which case the disease should disappear on transplanting to a more suitable soil.

On the basis of the results obtained from these preliminary field experiments, further experiments were then made on the possibility of transmitting the disease to normal plants (1) by artificial means, e.g., grafting and (2) by insects. In this summary the question of possible insect transmission is not touched on. Work on this aspect of the subject is being carried out by Mr. A. M. Massee of this Station, and has up to the present yielded negative results.

Having outlined the development of the investigation, the results obtained up to the present time will now be summarised.

1. *Cause—Experiments in Artificial Transmission.*

The fact that no organism was found associated with diseased stools, and the close similarity of the symptoms of the disease and those of the mosaic diseases of other crops, led to its provisional inclusion in this group of the Virus Diseases.

(*a*) *Transmission by Grafting.*—Experiments which have been carried out for two successive seasons indicate that, in the case of one variety—*Baumforth Seedling B*—mosaic symptoms are caused by a principle which can be transferred to normal plants by the method of grafting. Additional evidence is thereby forthcoming for including the disease among the Virus Diseases.

(*b*) *Transmission by other Methods.*—Experiments in the transmission of the disease by the transference of expressed juice from diseased plants to normal plants have, up to the present yielded negative results.

2. *Symptoms.*

The general symptom characteristic of the disease is a mottling or speckling of the foliage caused by the appearance of discoloured patches scattered over the leaf surface. These patches may be a distinct yellow or of a green colour but slightly paler than the rest of the leaf, and they may or may not be sunken. The mottling is sometimes accompanied by a curling or an irregular distortion of the lamina but this is not a constant character. Cases have also been noted in certain varieties showing an abnormal curling or distortion of the leaf but with no mottling. It will thus be seen that a considerable variation of leaf symptoms has been recorded. Such a variation has been observed in diseased stools of different varieties, and also latterly in diseased stools of the same variety, notably in the case of the variety *Baumforth Seedling B*. It remains to find by the method of transmission by grafting whether this is indicative of the presence of more than one mosaic disease.

3. *Varietal Susceptibility.*

A detailed survey of the disease carried out for four years on the variety trial plots at East Malling and on affected plantations in different parts of the country indicates that varieties differ considerably with regard to :—

(a) Rapidity with which initial infection spreads, i.e. the frequency of stools showing symptoms when the plantation has reached a given age.

(b) Intensity of leaf symptoms which a stool may ultimately show and the frequency of stools showing this advanced symptomatic condition when the plantation has reached a given age.

(c) The degree of dwarfing and degeneration referable to the disease and the frequency of stools thus affected when the plantation has reached a given age.

There is evidence that (a) may vary with the locality in which the variety is grown. (b) and (c), of course, are closely connected ; i.e. cases are common in which stools showing extreme leaf symptoms are also very stunted and dwarfed. But in some varieties severe leaf symptoms are but rarely associated with a marked decrease in vigour of growth, so that in such a variety a mere measure of the proportion of stools showing severe symptoms would not provide an adequate basis for the comparison of its susceptibility with that of another variety in which stools with equally severe leaf symptoms were also severely stunted and dwarfed.

There is but one strain on the trial plots at East Malling which has never shown a trace of mosaic—*Laxton's Abundance* (=*Bath's Perfection*). Several other strains of *Bath's Perfection* and varieties such as *Prior's Prolific*, *Red Antwerp B*, *Baumforth A*, show symptoms rarely and then only to a slight degree. Two years ago the recently introduced variety, *Lloyd George* would have been added to the above " resistant " group. Latterly, however, the disease appears to have become more serious in this variety.

In the case of the varieties *Red Cross*, *Norwich Wonder* and *Hornet A*, a stool free from leaf symptoms has never been observed. Among varieties that appear to suffer very much from the disease the following might be mentioned—*Scotch Victoria*, *Superlative*, *Fastolf A*, *Norwich Market* and *Reader's Perfection.*

4. *Experiments suggesting Control Measures.*

(*a*) *Dissemination by Vegetative Propagation.*—It has been shown by experiments that, in the case of several varieties at any rate, the disease is disseminated by vegetatively propagating from stools showing mosaic symptoms. There is also evidence that a stool which once develops mosaic symptoms does not subsequently return to a normal condition. It has not been found possible to raise disease-free stools from a stool which has once shown symptoms of mosaic,

i.e. the disease spreads very rapidly throughout the whole plant subsequently to initial infection. This indicates that the first essential for obtaining a healthy plantation is a careful selection of disease free stools from which to propagate.

(*b*) *Natural Spread in Plantation.*—There is evidence that, in the East Malling locality, the spread of infection through an experimental plot of the variety *Baumforth B*, at any rate, is not extremely rapid and that even when normal stools are planted in close proximity to diseased stools they may remain normal for a number of years. This suggests that, at least in the case of this variety, it may be possible to keep the disease in check by a systematic "roguing" of diseased stools, carried out periodically from the commencement of the plantation.

D. Spur Blight.

1. *Cause.*

The fungus *Didymella applanata* (Niessl.) Sacc. was found to be constantly associated with discoloured regions of the bark tissues of canes in the neighbourhood of non-developing buds. This fungus was isolated and grown on artificial culture media, and was proved to be the cause of the disease by inoculation experiments.

2. *Symptoms.*

The symptoms of the disease and the seasonal cycle of the fungus have been determined.

3. *Varietal Susceptibility.*

Records on the incidence of the disease on the trial plots at East Malling and elsewhere have been made. These records indicate that, as with the other diseases studied, some varieties are much more susceptible than others. Among the most susceptible varieties the following might be mentioned: *Reader's Perfection, Pyne's Royal, Superlative, Hornet A.*

4. *Control.*

No field experiments on control have been carried out up to the present date as work on this disease has only recently been started.

Our study of the disease in the field, however, suggests certain precautionary measures against it. There is evidence that young canes are infected by spores produced from fructifications of the fungus appearing on lesions on the fruiting canes. It would therefore be advisable to remove as many badly diseased canes as possible during the spring thinning of the stools.

It has also been observed that the attack of the disease is most severe in stools where the spawn has been allowed to grow up unchecked, thus hindering the circulation of air around the basal portion of the canes. A periodic hoeing out of superfluous spawn throughout the growing season is therefore advised.

# Section IV.

## Entomology.

# FURTHER EXPERIMENTS WITH TAR DISTILLATE WASHES.

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The results of the experiments undertaken at East Malling Research Station during the winter of 1924-25, with the object of testing the toxicity of tar-distillate washes to insect eggs under laboratory and field conditions, have already been published.* These experiments showed the possibility of evolving a fairly accurate method of measuring the efficiency of egg killing washes in the field. It was also shown that, although higher concentrations may slightly increase the actual efficiency of a tar-distillate, the optimum strength probably lies between five and ten per cent. At the same time information was obtained as to the efficacy of a tar-distillate wash against Winter Moth eggs in the field.

One of the experiments carried out in 1925 was with a standardized tar-distillate wash on the eggs of the Vapourer Moth (*Notolophus antiquus* L.), in the laboratory. In this experiment the percentage of viable eggs killed rose with the concentration of the spray, from 26 per cent. with a 3 per cent. concentration, to 99 per cent. with a 20 per cent. concentration. There was, however the anomaly that with the 5 per cent. treatment (No. IV) the percentage of eggs killed was 95. Since no explanation could be offered for this disproportionately high kill, it was decided to repeat the whole experiment in 1926 on a much larger scale. The object was to ascertain whether the anomalous result would again be obtained, and whether a rise in toxicity would, as in 1925, correspond with an increase in the concentration of the wash.

It was decided also to carry out further tests upon the eggs of the Vapourer moth, the Fruit Tree Red Spider and the Lackey Moth, and on the Black Currant Gall Mite.

The various tests undertaken in 1926 and 1927 were as follows :—

1. A comparative test at different strengths of a standardized tar-distillate wash on the eggs of the Vapourer Moth (*Notolophus antiquus* L.), in the laboratory.
2. A laboratory test on the eggs of the Vapourer Moth of two tar-distillate preparations, one containing low boiling tar acids, and the other high boiling tar acids.

* East Malling Research Station. Ann. Rept. 13th Year, Part II. (Supplement.) pp. 114-125 (1927).

3. A test on an extended scale, of a standardized tar-distillate wash on the eggs of the Vapourer Moth in the laboratory.
4. Tests of tar-distillate washes and dichlorbenzene at different strengths on the eggs of the Fruit Tree Red Spider (*Oligonychus ulmi* C. L. Koch), in the laboratory.
5. A test of two standardized tar-distillate preparations on the eggs of the Lackey Moth (*Clissiocampa neustria* L.), in the laboratory.
6. A test of a standardized tar-distillate wash on the Black Currant Gall Mite (*Eriophyes ribis* (Westw.) Nal.), in the laboratory.

1.—Laboratory Tests of the Toxicity of Various Strengths of Tar-Distillate Washes to Eggs of the Vapourer Moth.

The first trial of this type was undertaken at East Malling during January, 1925. The results of the trial, as already mentioned, indicated that a 5 per cent. concentration of a tar-distillate was more toxic to Vapourer Moth eggs than were the concentrations of $7\frac{1}{2}$ and 10 per cent. It seemed desirable, therefore, to repeat the experiment in the winter of 1926-27, on a much larger scale.

In order that ample material should be available, a large number of Vapourer Moths were reared during the summer of 1926, and as a result some 60,000 eggs were obtained. The egg batches were placed in a large wooden box fitted with a gauze lid. Here they remained under natural conditions until required. They were removed on February 9th and pinned on thin boards, the edges of which were coated with tree-banding grease to prevent the caterpillars from escaping when they hatched.

Added value is given to this trial by the very large number of eggs used, as the experimental error, never very small in work of this type, was thus considerably reduced. It may also be pointed out that it was found possible to use eggs laid by the same female, both in the test and in the "control," as described below.

*Application of Spray.*

The spray selected was the tar-distillate "Standard B." This preparation* was of the same composition as the one used in the 1925 experiments. It was prepared from anthracene or "green" oil, having a specific gravity of 1.1 and a range of boiling points as follows:—

| | | | |
|---|---|---|---|
| at | 220°C. | .. .. | 10 per cent. |
| | 260°C. | .. .. | 20 ,, |
| | 300°C. | .. .. | 40 ,, |
| | 380°C. | .. .. | 60 ,, |

* This preparation and two others referred to later in this paper were kindly supplied by Messrs. Newton Chambers & Co., Ltd., Thorncliffe, Sheffield. To them we wish to express our thanks, and also to their chief Chemist for his valuable assistance and advice.

The oil (75 per cent. was contained in the preparation) was emulsified by a resin-castor-oil soap, and gave a perfect emulsion when mixed with water. As far as could be determined this preparation was identical with the one previously used, and was made from materials which are commercially standardized.

The wash was used at the same concentrations as in the previous year. In addition, a proprietary preparation previously used in the 1925 trial was included, and applied at a strength of 10 per cent. This wash was included in this trial as a number of spare eggs was available.

The table shows the various strengths used, and the numbers of eggs treated.

| No. | Preparation. | Strength of Spray. | Numbers of Eggs used. |
|---|---|---|---|
| I.-IV. .. | Standard B. | 5% | 12,791. |
| V.-VIII. .. | ,, ,, | 7½% | 11,161. |
| IX.-XII. .. | ,, ,, | 10% | 11,909. |
| XIII.-XVI. .. | Unsprayed "Control" | — | 10,870. |
| XVII.-XX. .. | Proprietary Tar Distillate | 10% | 11,528. |

The spray was applied with an atomiser, the applications being made on February 10th. The following day the boards on which the egg hatches were pinned were hung in a cool greenhouse. From then onwards the sprayed and unsprayed (Control) batches were moistened with tap water once a week.

A close observation was kept upon the eggs, and hatching was first observed on February 23rd. From this time onward the hatched larvæ were removed daily and a record kept of their numbers, as a check on the egg counts to be made later.

Whilst hatching was going on it was observed that some eggs were parasitized by a minute Scelionid (*Telenomus dalmanii* Ratz).* It was not possible to record the number of parasites which hatched.

No hatching took place after April 24th. It will be seen therefore that hatching extended over a period of two months. Approximately the same hatching period was observed in 1925. Later in the year each egg-batch was examined under a binocular microscope. Counts of the numbers of hatched and unhatched eggs were made. It was found easy to distinguish the eggs which had hatched in the normal manner from those which had been parasitized.

The final count was begun on August 18th, and completed on September 25th.

The results of this trial are given in Table I.

* We are indebted to Dr. J. Waterston for the identification of this insect.

TABLE I.

*Comparative Effectiveness of Different Strengths of Tar-Distillate Washes against the Eggs of the Vapourer Moth, in the Laboratory.*

| Designation of Treatment. | Strength. | Total Counted. | Hatched. | Not Hatched. | | | % hatched of total. | % reduction. | % of viable eggs killed. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Not Hatched. | Dead before total emergence. | Eggs Parasitized. | | | |
| "Standard B." I.-IV. .. .. | 5% | 12,791 | 989 | 11,571 | 214 | 17 | 7·5 | 13·5 | 64 |
| "Standard B." V.-VIII. .. | 7½% | 11,167 | 657 | 10,280 | 210 | 20 | 6 | 15·5 | 72·5 |
| "Standard B." IX.-XII. .. | 10% | 11,909 | 432 | 11,285 | 186 | 6 | 3·5 | 17·5 | 83 |
| "Control" XIII.-XVI. .. .. | 0% | 10,870 | 2,319 | 7,833 | 117 | 601 | 21·5 | — | — |
| Proprietary Tar-distillate XVII.-XX. .. .. .. | 10% | 11,528 | 758 | 10,360 | 307 | 103 | 6·5 | 15 | 69 |

The first eight columns are self-explanatory. The normal hatch on the unsprayed " controls " was 21 per cent. Each treatment is seen to have caused a reduction in the number of eggs hatched, as tabulated in the ninth column. The percentage of viable eggs killed (column ten) was obtained by calculating the reduction of hatching as a percentage of the normal hatch. It will be seen that the percentage hatch in each case was calculated on the total number of eggs used in the treatment.

Parasitized eggs were not excluded from the totals. It will be seen that the percentage hatch would have been somewhat higher in the " control " series, if the parasitized eggs had not been included in the totals.

The table shows that, with the exception of the 10 per cent. treatment with a proprietary wash (XVII-XX), the percentage of viable eggs killed rises with the concentration of the spray. The 5 per cent. treatment destroyed 64 per cent. of the viable eggs, whereas in 1925 the percentage kill for the same treatment was 95—a difference of 33 per cent. In view of the close approximation of the figures obtained in this and in the previous (1925) trials with the other concentrations, it seems unlikely that the 1925 result represents the true toxic value of the 5 per cent. concentration, and that the 1926 figure is more correct.

The two strengths usually recommended for commercial spraying, $7\frac{1}{2}$ and 10 per cent., are seen to have killed respectively 72 per cent. and 83 per cent. of the viable eggs, as compared with 79 per cent. and 86 per cent. in 1925.

The proprietary tar-distillate treatment (XVII-XX) is seen to have killed 69 per cent. of the viable eggs. In view of the fact that the wash was used at a concentration of 10 per cent., this is not a satisfactory result.

## II.—A Comparative Trial of the Toxicity of Two Tar-Distillates, one Containing Low Boiling Tar Acids and the Other Containing High Boiling Tar Acids, to Eggs of the Vapourer Moth, in the Laboratory.

Since little information was available as to the effects upon insect eggs of tar distillate washes made from preparations of different constitution, a comparative trial was undertaken of two tar-distillates, one containing tar acids of low boiling points, the other containing tar acids of high boiling points.

*Method of obtaining Material, and Technique Employed.*

The eggs used were obtained in the following manner. The larvæ hatched from the unsprayed (control) egg batches used in the 1925 experiments were removed to apple trees growing in the open and the shoots upon which they were placed were enclosed in muslin " sleeves," to protect the larvæ from Hymenopterous parasites. The moths on emerging were removed to a green-house and placed in a large cage, apple leaves being provided for them to lay their eggs on.

As a result, more than 300 egg batches were obtained, and these were kept in the open until the time of spraying.

Since former experiments had shown that the percentage of eggs normally hatching is subject to considerable variation, a different method of technique was adopted in this trial. Each egg batch was divided into two, one portion forming part of the unsprayed " control," the other portion being sprayed. A separate control was thus provided for each egg batch treated. Half batches of eggs were pinned on boards and numbered 1 to 330. The corresponding half batches were pinned on other boards and also numbered 1 to 330. Thus the two portions of each egg batch bore corresponding numbers. The factor of occasional infertility and the irregularity in results due thereto were in this way eliminated, since any particular egg batch could be discarded if the unsprayed half failed to hatch. The edges of the boards were smeared with tree-banding grease in the usual manner.

*Composition of Sprays used.*

The two tar distillate preparations used in this series of experiments were made from creosote oil, emulsified in the same way as the " Standard B " preparation referred to in the previous section. The preparation " T.A." contained 25 per cent. of low boiling tar acids, boiling at 190°C to 215°C. The preparation " T.B." contained 25 per cent. of high boiling tar acids, boiling at 220°C to over 300°C (80 per cent. at 300°C). Both preparations formed good emulsions which mixed well with water and did not separate out on standing.

The object in selecting these preparations for a comparative test was to ascertain whether the toxicity of a tar distillate wash could be referred to any differences in the tar acid content. Naturally, with such variable materials as the tar distillates it is very difficult to test the various constituents, even if it were possible to make preparations in which definite amounts of the constituents were present. It has sometimes been suggested, however, that the tar acids are an important factor in determining toxicity. The experiments in this section were therefore made in the hope that one of the preparations might behave differently from the other and so something which would serve as a starting point for further work would be obtained. It was recognised however, that as with all tar distillates, the standardization would have to be rather widely drawn.

*Application of Sprays.*

The egg batches were sprayed by means of an atomiser on January 20th, 1927. The eggs were examined each day subsequently, and hatching was first observed on February 22nd on the unsprayed " controls." The daily hatchings of larvæ were recorded, the last date on which any eggs hatched being April 21st.

TABLE II.

*Comparative Effectiveness of Tar-Distillate Washes of Different Compositions against Vapour Moth Eggs in the Laboratory.*

| Batch number. | Treatment. | Total Counted. | Hatched. | Not Hatched. | | % hatched of total. | % reduction. | % viable eggs killed. |
|---|---|---|---|---|---|---|---|---|
| | | | | Not hatched. | Larvæ dead before total emergence. | | | |
| 1-84 | Unsprayed "Control" | 9,138 | 4,908 | 4,112 | 118 | 53·5 | — | — |
| 1-84 | Standard T.A. at 10% | 11,038 | 50 | 10,939 | 49 | ·5 | 53·5 | 99 |
| 85-168 | Unsprayed "Control" | 12,220 | 5,600 | 6,134 | 486 | 46 | — | — |
| 85-168 | Standard T.B. at 10% | 12,682 | 50 | 12,622 | 10 | ·5 | 45·5 | 99·5 |
| 169-245 | Unsprayed "Control" | 4,489 | 2,352 | 2,119 | 180 | 52·5 | — | — |
| 169-245 | Standard T.A. at 10% | 5,150 | 493 | 4,482 | 175 | 9·5 | 43 | 81·5 |
| 246-330 | Unsprayed "Control" | 4,851 | 2,284 | 2,363 | 204 | 47 | — | — |
| 246-330 | Standard T.B. at 10% | 4,411 | 207 | 4,137 | 67 | 4·5 | 42·5 | 90 |

Thus it will be seen that the hatching extended over a period of two months. In the two previous experiments also, the hatching period lasted approximately two months. As already mentioned, the larvæ were protected from parasites by being enclosed in muslin bags. The eggs were also protected from the Scelionid parasite. The precaution was justified since none of the eggs used in the trial was found to be parasitized.

During November and December each egg was examined under a binocular microscope. The numbers of hatched and unhatched eggs in the sprayed and unsprayed series were recorded. The results obtained are shown in Table II.

It will be seen that the percentage hatch in each treatment is calculated on the total number of eggs used in the treatment; infertile egg batches were not included.

Both washes are seen to kill about the same percentages of viable eggs, the averages for "Standard T. A." and "Standard T.B." being 90 per cent. and 94 per cent. respectively. The difference in killing power is not sufficiently great to warrant the belief that the preparation containing the high boiling tar acids (T.B.) is the more effective under the conditions described. Both washes however gave high kills and from this standpoint must be regarded as satisfactory ovicides for the eggs of the Vapourer Moth.

### III. Experiments with a Standardized Tar-Distillate Wash ("Standard A") on the Eggs of the Vapourer Moth, in the Laboratory.

A number of Vapourer Moth eggs (about 27,000) obtained during 1926, were available for this trial, which was complementary to the one made in 1925 with "Standard A" wash. This preparation differed from "Standard B" in that it was made from "commercial light oil," and had a lower range of boiling points, as the following analysis shows:—

| | | | |
|---|---|---|---|
| at | 200°C. | .. .. | 13 per cent. |
| | 220°C. | .. .. | 51 ,, |
| | 250°C. | .. .. | 78 ,, |
| | 300°C. | .. .. | 90 ,, |

The eggs were treated in a manner similar to that adopted in 1925. The spray was applied on January 20th, 1927, by means of an atomiser, the strength of application being 10 per cent. The unsprayed "control" egg batches were moistened with tap water.

The final counts were made during January, 1928, with the aid of a binocular microscope. Fig. I. shows unhatched Vapourer Moth eggs, previously sprayed with the tar-distillate "Standard A", Fig. II. shows hatched eggs, laid by the same female and left unsprayed.

The results obtained in this trial are shown in Table III.

TABLE III.

*Toxicity of a Standardized Tar-Distillate Wash ("Standard A") to Eggs of the Vapourer Moth in the Laboratory.*

| Treatment. | Total number of eggs counted. | Number of eggs hatched. | % hatched. | % reduction in hatching. | % viable eggs killed. |
|---|---|---|---|---|---|
| Unsprayed .. | 10,289 | 5,078 | 49·5 | — | — |
| Standard A. at 10% .. | 16,935 | 663 | 3·5 | 46 | 93 |

The figures in the first four columns are self explanatory and the percentage of viable eggs killed (93) is calculated by the method previously described (p. 141.) The table shows that the percentage of hatched eggs in the "controls" was 49.5 per cent., and that the percentage reduction in the hatching of eggs sprayed with "Standard A" was 46.

In experiments conducted in 1925 on the eggs of the Hop-Damson Aphis, the percentages of viable eggs killed by "Standard A" wash were 35 and 56, in the field and in the laboratory respectively.* The results of the trials with this wash indicate that it is less effective against eggs of the Hop-Damson Aphis than against those of the Vapourer Moth. It must be noted, however, that on the eggs of the Hop Damson Aphis the strength used was 7½ per cent. and not 10 per cent.

## IV. LABORATORY TRIALS OF TAR-DISTILLATES, DICHLORBENZENE, AND MIXTURES OF THESE ON THE EGGS OF THE FRUIT TREE RED SPIDER.

During the course of the trials upon eggs of various insects, it had been frequently noticed that the washes used did not affect the eggs of the Fruit Tree Red Spider (*Oligonychus ulmi*), so often present upon the shoots and even attached to the eggs included in the trials. It was decided therefore to carry out a test on the eggs of the Fruit Tree Red Spider in the laboratory.

*Material Available.*

Fortunately Red Spider eggs were very numerous on a variety of plum stock, Common Mussel. Shoots from these stocks bearing sufficient eggs were selected, cut off, and placed in pots containing moist sand. In all sixteen pots were used, each pot containing twelve shoots. The pots were kept in the laboratory greenhouse.

* East Malling Research Station, Ann. Report 13th Year, Part II. (Supplement), pp. 114-125 (1927).

*Application of Sprays.*

The sprays used were a proprietary tar-distillate, two tar-distillates of known composition, and dichlorbenzene, alone and mixed with a tar-distillate. The two tar-distillates of known composition were "Standard A" and "Standard B." The dichlorbenzene was made into an emulsion with neutral paraffins, and contained 60 per cent. of dichlorbenzene, and 40 per cent. of emulsifying material; it mixed well with water and was used both alone and mixed with "Standard A" at various strengths, as shown in the following table.

| No. | Designation of Treatment. | Strength of Spray |
|---|---|---|
| I. | Unsprayed | 0 to 100 |
| II. | Standard A. | 10 to 90 |
| III. | Standard B. | 10 to 90 |
| IV. | Proprietary A. | 10 to 90 |
| V. | Proprietary B. | 10 to 90 |
| VI. | Proprietary C. | 10 to 90 |
| VII. | Dichlorbenzene | 1 to 99 |
| VIII. | Dichlorbenzene | 2½ to 97½ |
| IX. | Dichlorbenzene | 5½ to 95 |
| X. | Dichlorbenzene | 5 to 95 |
| | Standard A. | 10 to 90 |
| XI. | Dichlorbenzene | 2½ to 97½ |
| | Standard A. | 10 to 90 |
| XII. | Dichlorbenzene | 1 to 99 |
| | Standard A. | 10 to 90 |

Almost exactly two pints of spray were used per pot, the shoots being sprayed by means of a small hand pressure sprayer. The spraying was done on the 10th and 11th of February, 1926.

Hatching commenced in the first week of March, and the shoots were kept under observation till it was considered that hatching had finished. The shoots were then taken to the laboratory, examined under a binocular microscope, and the numbers of hatched and unhatched eggs were ascertained.

The results are shown in Table IV.

TABLE IV.

*Comparative Effectiveness of Different Washes against Red Spider Eggs, in the Laboratory.*

| Treatment. | Strength. | Total number of eggs. | Hatched. | Per cent. hatched. | Per cent. reduction | Per cent. viable eggs killed. |
|---|---|---|---|---|---|---|
| Unsprayed | — | 5645 | 5230 | 92.5 | — | — |
| Standard A. | 10% | 3672 | 3121 | 85 | 8 | 8.5 |
| Standard B. | 10% | 1282 | 1162 | 90.5 | 2 | 2 |
| Proprietary A. | 10% | 2080 | 1835 | 88 | 4.5 | 5 |
| Propietary B. | 10% | 1206 | 1074 | 89 | 3.5 | 4 |
| Proprietary C. | 10% | 2648 | 2129 | 80.5 | 12 | 13 |
| Dichlorbenzene | 1% | 1888 | 1640 | 87 | 6 | 6 |
| Dichlorbenzene | 2½% | 1161 | 984 | 85 | 8 | 8.5 |
| Dichlorbenzene | 5% | 1823 | 1603 | 88 | 4.5 | 5 |
| Dichlorbenzene<br>Standard A. | 5%<br>10% | 2357 | 2142 | 91 | 2 | 2 |
| Dichlorbenzene<br>Standard A. | 2½%<br>10% | 1358 | 1032 | 76 | 16.5 | 17 |
| Dichlorbenzene<br>Standard A. | 1%<br>10% | 3042 | 2414 | 79.5 | 13.5 | 14.5 |

The percentage of viable eggs killed was calculated by the method already described.

It will be seen that the percentage hatch of eggs in the "control" was 92.5 whilst in the treated sections it varied from 76 to 90.5. The small percentages of viable eggs killed by the treatment are very striking. The most efficient spray was dichlorbenzene with 10 per cent. "Standard A," but even with this only 17 per cent. of the viable eggs were killed.

It seems clear therefore that the eggs of the Fruit Tree Red Spider are not much affected by the preparations used in these experiments. More recent work in this direction has confirmed these results.

Fig. 3 shows typical Red Spider eggs, as deposited on the shoots and spurs. The eggs illustrated were sprayed with 10 per cent. concentration of a proprietary tar-distillate preparation. Two months later all the eggs hatched and the mites developed in a normal manner.

The above results are of interest in view of the claims sometimes made that tar-distillate washes are toxic to Red Spider eggs. A very large number of tests have been made in this connection from time to time, and with various proprietary and other preparations, but no results of any value have been obtained.

On these lines experiments were undertaken at East Malling during the winter of 1925-26, and again in the winter of 1926-27, to test the toxicity of tar-distillate washes to which (*a*) napthalene and (*b*) colloidal sulphur had been added. These trials also yielded negative results.

## V. Experiments on the Eggs of the Lackey Moth in the Laboratory.

Two tents of nearly fully grown larvæ were obtained from a neighbouring farm in June, 1926, and were reared under natural conditions. As soon as the moths emerged from the pupæ, in the autumn, they were transferred to a large wooden box containing apple shoots. The moths deposited all their eggs on these shoots, and 150 egg-bands were thus obtained. These egg-bands were divided into three lots of 50 each, labelled A, B, and C respectively.

*Sprays Used.*

The spray materials were two tar-distillate preparations of known composition—"Standard A" and "Standard B". The eggs were sprayed by means of an atomiser on February 11th, 1927. Series A was sprayed with 10 per cent. "Standard A" preparation, Series C with 10 per cent. "Standard B," and Series B was left unsprayed as a control.

The shoots with the egg-bands attached were placed in boxes containing moist sand and kept in the open under a lean-to shelter. The eggs began to hatch during the last week of April, 1927, and hatching had finished by the second week of May. The shoots were then taken into the laboratory and counts of the numbers of hatched and unhatched eggs were made.

The figures obtained are shown in Table V.

Table V.

*Toxicity of Tar-Distillate Washes to Eggs of the Lackey Moth, in the Laboratory.*

| Treatment. | Per cent. hatched. | Per cent. viable eggs killed. |
|---|---|---|
| Standard A at 10% | 24.5 | 56.5 |
| Standard B at 10% | 18 | 68 |
| Unsprayed "Control" | 56 | — |

It will be seen that 56 per cent. of the unsprayed eggs hatched. " Standard A " and " Standard B " apparently killed 56.5 per cent. and 68 per cent. respectively of the viable eggs. Of the unhatched eggs 50 per cent. contained dead larvæ which appeared to be in an advanced state of development. The larvæ which hatched were found to develop normally.

It is evident from the above figures that the tar-distillates used in this test are not highly toxic to eggs of the Lackey Moth.

In another experiment carried out in 1925 a number of egg-bands were soaked for 24 hours in a 10 per cent. strength of a proprietary tar-distillate. three months later more than 90 per cent. of the eggs hatched.

## VI. A Laboratory Test of a Tar Distillate Wash on the Black Currant Gall Mite.

A small trial was undertaken in the spring of 1927 to determine whether tar-distillates are toxic to the Black Currant Gall Mite, as statements were sometimes made that such preparations are effective in controlling " Big Bud."

The material for this experiment consisted of 200 Baldwin Black Currant cuttings, taken from a plantation badly infested with " Big Bud." The cuttings were set in moist sand in two large wooden boxes and kept in a cool greenhouse.

The spray used was " Standard A" at 10 per cent., applied by means of an atomiser. The application was made on February 11th, 1927, and the unsprayed " control " cuttings (100) were slightly damped with tap water.

The cuttings were kept in a cool greenhouse from the time of spraying until the normal migration period of the mites had finished. Periodical examinations were made and the first date of migration was noted (March 27). From then onwards mites were observed on the outer bud scales of the " big buds " of the sprayed and unsprayed cuttings. They continued to leave the galled buds until the third week of April.

It was not possible to estimate the number of mites migrating from the " big-buds," but it was considered that the sprayed and unsprayed cuttings bore the same number of active mites on their outer bud scales. Certainly there was no evidence to suggest that the tar-distillate in question, *used as a dormant winter wash*, was toxic to the Black Currant Gall Mite, and as the preparation is typical of its class, its behavour is probably more or less the same as that of other tar-distillates. Wide experience of commercial spraying tends to confirm this impression.

During the winter the mites are living inside the buds, where they cannot be reached by any spray. Tar-distillate washes, used during the migratory period are highly, toxic to the mites. These preparations, however, are essentially dormant winter washes, and cannot be used at the migratory period.

The writers are greatly indebted to Miss M. Gillman (Dip. Hort.) for valuable assistance in the laborious task of egg counting.

## Summary.

Experiments with tar-distillate washes carried out at East Malling Research Station in 1926 and 1927 are described.

Attention is called to certain improvements in technique and in the methods of obtaining adequate supplies of material (*i.e.*, eggs).

The experiments showed :—

1. That the percentage of viable eggs of the Vapourer Moth (*Notolophus antiquus* L.) killed by a tar-distillate wash (" Standard B ") rises with the concentration of the wash. The 5 per cent. concentration did not, as in the 1925 experiment, give a disproportionately high kill.

2. That in the comparison of a standardized tar-distillate (" Standard B ") with a proprietary preparation, used at equal strengths, the former killed 83 per cent. and the latter 69 per cent. of the viable eggs of the Vapourer Moth.

3. That two tar-distillates, one containing low boiling tar acids and the other high boiling tar acids, gave almost identical kills when tested on eggs of the Vapourer Moth, the first preparation giving an average kill of 90 per cent., and the second 94 per cent. of the viable eggs.

4. That a standardized tar-distillate (" Standard A ") at 10 per cent. killed 93 per cent. of the viable eggs of the Vapourer Moth.

5. That tar-distillate preparations, dichlorbenzene, and mixtures of tar-distillates and dichlorbenzene, were all ineffective against the eggs of the Fruit-Tree Red Spider (*Oligonychus ulmi* C. L. Koch) at the strengths used.

6. That the two standardized tar-distillate washes (" Standard A " and " Standard B ") were only moderately toxic to eggs of the Lackey Moth (*Clissiocampa neustria* L.) under the conditions described, the percentages of viable eggs killed by these washes being 56.5 and 68 respectively.

7. That a tar-distillate wash (" Standard A ") was not toxic to the Black Currant Gall Mite (*Eriophyes ribis* (Westw.) Nal.) when used *as a winter wash* and at a concentration of 10 per cent.

FIG. 1.

Eggs of the Vapourer Moth (*Notolophus antiquus* L.) sprayed with a tar-distillate wash ("Standard A") at 10 per cent. Only 3 per cent. of the eggs hatched. (Highly magnified.)

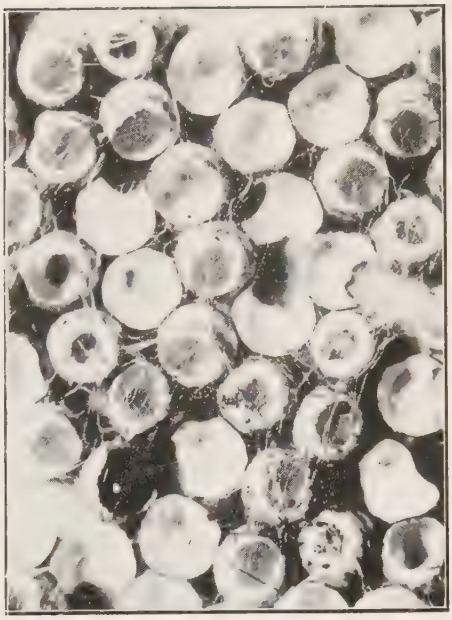

FIG. 2.

Eggs of the Vapourer Moth left unsprayed (Control). 49 per cent. of the eggs hatched. The eggs in Figs. 1 and 2 were laid by the same moth. (Highly magnified.)

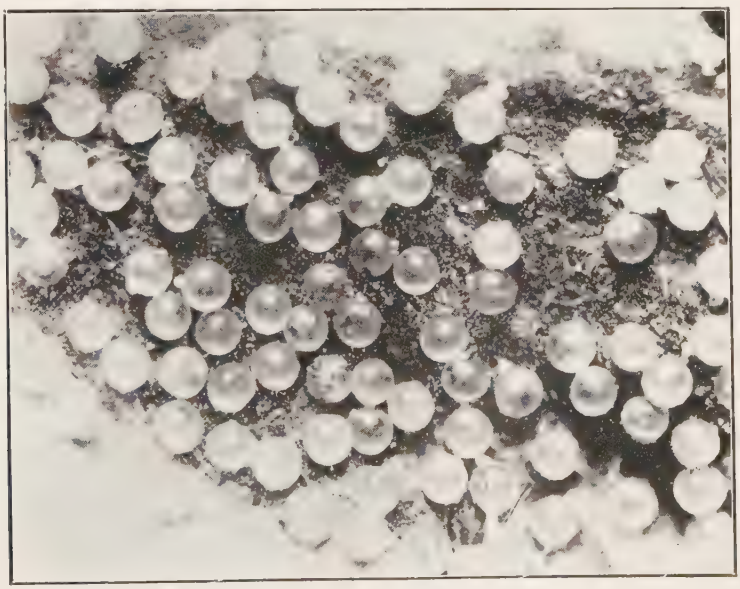

FIG. 3.

Eggs of the Red Spider (*Oligonychus ulmi* C. L. Koch) sprayed with a proprietary tar-distillate wash at 10 per cent. 100 per cent. of the eggs hatched. (Very highly magnified.)

Attack of Black Currant Gall Mite on Red Currant

# THE BLACK CURRANT GALL MITE ON RED CURRANTS.

By A. M. MASSEE.

The Black Currant Gall Mite was first recorded on Red Currants by Nalepa* in 1893, but details of the damage caused by this acarus are not described. In 1907, Theobald† referred to a peculiar attack of the Black Currant Gall Mite on Red Currants. This report appears to be the first describing the form of damage caused by the Gall Mite.

Since that time several instances of mite attack on Red Currants have been reported, but it was considered that the mites did not affect the bushes to any marked extent, and in consequence very little attention has been paid to this pest.

During the past three seasons, however, this pest has become unusually common, and is the cause of the failure of several Red Currant plantations, situated in various parts of Kent. Canterbury, Brenchley and Maidstone are among the worst affected areas.

## Symptoms of the Disease.

The Gall Mite does not produce on Red Currants the typical " Big Buds " which are so common on Black Currants, but in instances of severe infestation the buds tend to swell out somewhat, more especially those at the base of the bush. The swollen buds can be detected from November to May. In some varieties (i.e., Fay's Prolific), a dense growth of buds is produced ; these buds do not develop normally, and eventually dry out, as shown in the illustration.

When infested buds are examined with the binocular microscope, several thousands of mites, in all stages, will be found in the centre of the buds. Eggs are also found inside the infested buds.

## Detection of the Mites in the Field.

It is difficult to detect the presence of mite on the bushes during the autumn or winter, since all the buds are in a dormant state, and the symptoms of the disease is not apparent. However, the diseased buds may be seen readily in the spring as soon as the buds commence to open. At this season the mite infested buds remain in a dormant condition and many of them are somewhat swollen. These dormant buds are frequently referred to as " blind " buds. Many fruit growers consider the " blind " buds are caused as a result of bird attack during the winter months.

* Anz. Ak. Wien, V.30., P. 105, 1893.

† Report on Economic Zoology for the year ending April 1st, 1907. P. 53. (1907).

### Habits of the Mites.

The mites live on the undersides of the leaves during the spring and summer months. Immature stages and the eggs are present on the foliage. In the autumn the mites migrate to the buds, which they enter, and remain inside until the following spring. During the first or second week of April, according to the season, the mites leave the buds and live freely on the leaves, and the infested buds eventually dry out.

### Varieties Attacked.

Raby Castle and Fay's Prolific undoubtedly suffer most from the attacks of the mite. Many other varieties, however, suffer to a lesser extent. Scotch Red was noted to be very badly attacked during the spring of 1927, the attack being quite as serious as that of Raby Castle, which was growing nearby. New Red Dutch, La Constante and Old Red Dutch are also frequently infected with the mite.

### Control Measures.

Preliminary spraying experiments have been carried out during the past year, and there is reason to believe that it will be possible to control the mite by applying a lime sulphur spray to the bushes, in the spring, as soon as the buds open. At this period the mites commence to leave the buds, and are killed by the lime sulphur. Experiments on these lines are proceeding, and full details will be published in a later report.

# NOTE ON THE USE OF TAR-DISTILLATE SPRAYING AND OF GREASEBANDING AGAINST THE WOOLLY APHIS OF APPLE

## (*ERIOSOMA LANIGERUM* HAUSM.)

By RICHARD H. LE PELLEY.

During the course of an investigation of the Resistance of Apple to the Woolly Aphis, made at East Malling Research Station in 1925 and 1926, the writer kept a close observation on the pest in a neighbouring commercial orchard both in order to study the life history of the insect on apple and to compare its incidence under natural conditions with that under the conditions of artificial infection used in the " Resistance " experiments.

The portion of orchard selected for more particular study contained about 100 old large trees mainly but not entirely of the variety Bramley's Seedling, which all bore evidence of longstanding attack by Woolly Aphis. Examination of the trunks and main branches of these trees in January and February, 1925, showed that hibernating Woolly Aphids were present here and there under pieces of loose bark or deeply hidden in cracks. Several small colonies of living insects could be found on most trees when a careful search was made. This suggested that a test should be made of a combination of grease-banding (as advised by Theobald)* and tar-distillate spraying for the control of the insect. An experiment was planned to test this in the commercial orchard described. It should be mentioned that this tar-distillate spraying experiment was not planned in the exaggerated hope that it would prove an economical measure to apply a tar-distillate wash solely against the Woolly Aphis, but in order to increase our knowledge of the general usefulness of such a wash by a study of its effect on this one pest for the control of which alone it is not generally used. Laboratory tests of the powers of about fifteen liquids (including a tar-distillate wash at different strengths) to dissolve the " wool " and wet the surface of Woolly Aphids were made. Detailed results of these will not be given, but the tar-distillate (a proprietary brand) proved to be equal to the best and better than the majority of the other liquids used, in rapidly wetting the whole surface of the insect, and it was also shown to be rapidly toxic. The " wool " appeared to be rapidly dissolved by the tar-distillate at 7 per cent. and 10 per cent., and was no impediment to the action of the wash in killing the insect immediately on contact.

* Theobald, F. V. The Woolly Aphid of the Apple and Elm. Parts 1 and 2, Jour. of Pomology, II., 1920.

For the spraying experiment, thirty of the large trees in the commercial orchard were selected, of which fifteen were sprayed while the other fifteen remained unsprayed as "controls." Ten of the sprayed and ten of the unsprayed trees were grease-banded. In addition thirty other trees were grease-banded. The bands were attached between the 15th and 25th of November when the Woolly Aphis had become dormant and was no longer strikingly evident on the branches.

The fifteen selected trees were sprayed on December 17th with the wash described by Goodwin, Massee and Le Pelley,* and named Standard B. It was applied at 10 per cent. strength with a hand-manual machine giving a pressure of 75-80 lbs. per square inch. The day on which the application was made was fine and bright, the spray dried on the trees and no rain fell for some time afterwards.

On April 14th, 1926, an examination resulted in the locating of a total of six colonies of Woolly Aphis on the fifteen sprayed trees and thirty on the fifteen unsprayed trees. By May 25th the insect was multiplying, and colonies increasing in size and clearly visible on a casual inspection, were present. A careful examination on this date resulted in the following numbers of colonies being found. The first ten trees in each column were grease-banded.

| | *Sprayed.* | *Unsprayed Controls.* |
|---|---|---|
| | 2 | 18 |
| | 5 | 31 |
| | 1 | 16 |
| | 8 | 19 |
| | 5 | 20 |
| | 11 | 20 |
| | 1 | 11 |
| | 4 | 6 |
| | 5 | 18 |
| | 0 | 15 |
| | 1 | 50 |
| | 8 | 16 |
| | 1 | 3 |
| | 12 | 16 |
| | 3 | 11 |
| Total | 67 | 270 |

The colonies were all on the trunks and large branches, and as the number of colonies on grease-banded trees were not significantly smaller than those on

* Goodwin, W., Massee, A. M., and Le Pelley, R. H. Tar-distillate washes. Their comparative effectiveness, etc. Jour. of Pomology, V., October, 1926.

the trees not grease-banded, it is clear that, at least on its first appearance, each colony must have begun from an insect, or a comparatively small number of insects, which had hibernated on the trunk or large branch and begun increasing when the weather became sufficiently warm in spring. Such small hibernating groups could with careful search be found under bark or in cracks at any time during the winter.

No detailed study of the progressive infestation of one of these trees was made, but it is evident that in the early summer when the colonies had considerably increased in size, insects would wander from them and settle down elsewhere. Thus each overwintering colony can be considered as a " centre of infection," and the ultimate result of a sufficient number of such colonies having overwintered above ground will be a heavy infestation during the summer. Observations showed that an undisturbed attack had generally reached the current year's growth by the beginning of August.

The figures given show that the spraying had a very decided effect on the number of hibernating colonies that remained to reproduce in the spring, but it left sufficient to enable the insect to infest the tree heavily by the middle of the summer, owing to its high rate of increase. Late in the summer both sprayed and control trees were heavily attacked. It is possible that if the spray were applied at a higher pressure less colonies would survive than was the case in this experiment.

There was very little root attack present and the thirty grease-banded trees not used in the spraying experiment were as heavily attacked, both early in the spring and throughout the summer, as trees that had not been banded. No migration from the roots to the branches was observed in the spring. In this orchard the perennial attack on the branches is maintained by means of the insects which pass the winter above ground.

Observations were made in an orchard in another part of the County which was heavily attacked by Woolly Aphis both above and below ground, and which was grease-banded and sprayed commercially with a proprietary tar-distillate in the winter of 1925.

Several hundreds of trees were grease-banded and sprayed, but a heavy attack began early in 1926 and this had to be checked by " hand-painting " the colonies during the summer. A heavy root infestation was present in this orchard and the upward migration covered the lower parts of many of the trees below the bands. The attack during the summer after the spraying and grease-banding was due to two causes, (1) the failure of the wash to reach certain of the colonies protected beneath bark and deep in the cracks of galls, and (2) the ability of certain of the small insects to pass between band and tree. Further work is necessary on the movements of the Woolly Aphis between branches and roots and *vice versa*, and the relative damage caused on branches and roots, before

grease-banding can be definitely considered a useful measure. It seems at least possible that if grease-banding confines the insects to the roots where they can be less easily attacked, it may not be advantageous to the ultimate health of the tree.

The following points appear from the tests and discussion :—

1. The efficacy of grease-banding as a control measure for Woolly Aphis seems to be limited by the fact that the insect can usually overwinter above ground in this country and that it is very difficult to ensure the destruction of all these overwintering insects ; and by the difficulty of applying the bands in commercial practice (especially on old trees or trees with a rough bark) sufficiently soundly to prevent a small number of insects from finding a way up.

2. Tar-distillate spraying for the specific object of controlling Woolly Aphis would not usually be an economical measure.

3. In addition to its other uses a tar-distillate wash destroys a large proportion of the Woolly Aphis hibernating above ground, and this should be taken into account when assessing the general value of Tar-distillate spraying. Its application should considerably decrease the labour of " hand-painting " the colonies of the insect where this palliative measure is employed.

# NOTES ON INSECT PESTS FOR THE YEARS, 1926-27.

By A. M. MASSEE.

The Apple Bud Weevil (*Anthonomus cinctus* Koll.).

The Apple Bud Weevil, a beetle closely related to the familiar Apple Blossom Weevil, was first recorded at East Malling during 1922. In that year it was found destroying the developing fruit buds of the variety of apple Newton Wonder. Twenty-four specimens of the adult weevil were obtained. Many larvæ were found in the buds, but for some reason they did not complete their life-cycle under laboratory conditions.

While pruning operations were being carried out at East Malling during March, 1927, a number of buds of the variety Bismarck were noticed to be somewhat swollen, but in a dormant condition. These abnormal buds were found to contain the larva of a small weevil. At this period the majority of the buds were beginning to break, thus it was possible to pick out the infected buds without difficulty.

The infected buds were collected and the larvæ were bred out. The weevil proved to be " The Apple Bud Weevil," (*Anthonomus cinctus* Koll.).

It is of interest to record the occurence of this rare beetle at East Malling, since it has not been seen in the district for the past five years. However, it seems probable that it has been present in small numbers in the plantation during the period, but may have been overlooked, since isolated specimens would be difficult to find on the trees.

A detailed account of the life-cycle of this weevil has been published by F. R. Petherbridge and J. W. Cowland. Their article appears in Annals of Applied Biology, vol. XI., Nos. 3 and 4, October, 1924.

II. The Pear and Cherry Slugworm (*Eriocampa limicina* Cam.)

The Pear and Cherry Slugworm has been very common in many parts of Kent during the past two years. It is reported that several Pear and Cherry orchards have been defoliated by the slugworm. Pear plantations in the Maidstone area have suffered very considerably, in some instances the trees being defoliated by the beginning of August.

At East Malling, both Pears and Plums were attacked by this pest to a serious extent, during the months of July, August and September.

Fifteen varieties of Pears were affected. Some sorts were infected to a greater extent than others, but none appeared to be free. Several varieties of Plums growing in the same plantation were also attacked to a lesser degree.

Some information of the degree of infestation was obtained on a number of bush Pears. Conference, Chaumontel, and Souvenir de Congres, were completely defoliated. Emile d'Heyst, Fertility, Hessle and Durondeau lost most of their foliage by the end of July, but were not considered to be as badly attacked as Conference. The more resistent varieties noted were, Beurre Alexander Lucas, Reines des Poires, Georges Bouchier and Fondante de Thirriott.

Many varieties of Cherries were also defoliated by this slugworm. At East Malling they were feeding upon the foliage of sweet and sour Cherries. However, the attack commenced too late in the year to cause any appreciable damage.

The sawflies (adult stage of the slugworm) were first seen in the plantation on May 30th. From that time numerous specimens were seen on the Pear leaves.

The larvæ (slugworms) are difficult to find in their early stages. This is rather curious, because they usually feed on the upper surface of the leaves, where one would expect to find them without difficulty. After the larvæ have moulted for the third time, they feed very rapidly upon the upper surface of the leaves, leaving the under surface intact. The leaves turn brown, and eventually fall off. In severe instances of attack the trees are completely defoliated, as shown in Fig. B. Fig. A shows one of the most resistant varieties of the Pear.

Two broods of this sawfly occur in some years, but only one brood was recorded at East Malling in 1927.

The slugworm is quite easy to control. Where possible the trees should be sprayed with Arsenate of Lead at the rate of four pounds of Lead paste to 100 gallons of water, as soon as the slugworms are seen on the foliage. If applied well, only one spraying is necessary.

The adverse weather conditions of 1927 rendered it almost impossible to spray against this pest before most of the damage had been done.

In mixed plantations, where currants or other soft fruits are growing under the Pears or Plums, it is not possible to use Arsenate of Lead, and the use of a non-poisonous spray must be resorted to.

### III. The Occurence of a Little-known Mite (*Eriophyidae*) on Apple.

During 1926 and subsequently in 1927 the writer's attention was called to the presence of a species of Gall Mite infesting Apple leaves in newly planted orchards at East Malling.

This mite has been found previously on wild crab Apples growing in the New Forest, Hampshire, and at Sevenoaks, in the summer of 1925.

Specimens of the mite were examined with the aid of a microscope, and were found to belong to the sub-family *Phyllocoptinae*. The species being *Phyllocoptes schlechtendali*, Nalepa.

This acarus was very common on the variety of Apple, Hormead Permain

A

Pear Tree highly resistant to Slugworm in 1927.

B

Pear Tree Defoliated by Slugworm.

during the summer of 1927, and much damage was caused to the foliage as the result of mite attack. The fruit was also infested in some instances. The mite punctures and feeds upon the epidermis of the Apple, the result being slightly pitted and speckled fruit.

The life-cycle of this mite is not known in detail, but a few points of interest have been ascertained and will be referred to briefly.

The mites hibernate under bud scales and also under loose bark. It is usual to find only five or six individuals under a single bud scale. They do not appear in large colonies as is frequently the case with closely allied species. The mites begin to feed as soon as the buds commence to break in the spring. Their eggs have been found on the lower surface of the leaves. It is not known when oviposition takes place. Eggs have not been found in the winter months.

This mite was first recorded by Nalepa, from central Europe in 1890. It was described and named by Nalepa at that date. More recently it has been found in America, and appears to be of some importance in that country.

## IV. Two Species of Gall Mites New to Britain.

During 1926 and 1927 two species of Gall Mites were found on Lilac. The material was obtained from private gardens at East Malling and Sevenoaks.

The malformation of the buds of Lilac, caused by the commoner of the two mites is very characteristic, and can be recognised without difficulty when the symptoms of the disease are known. This mite infests the new buds, generally those towards the tip of the shoots, causing them to dry out completely as a result. The attacked shoots become stunted and weak.

The mite belongs to the genus *Eriophyes*, and was described by Nalepa in 1890. The species being *Eriophyes löwi* Nalepa.

It has been recorded previously from Austria, Italy, Germany and France.

The second species of mite found on Lilac is not so common as the bud destroying species. It was described in detail by Nalepa in 1924, who named it *Phyllocoptes massalongoi* Nalepa.

The mites of the genus *Phyllocoptes* lives freely upon the leaves, producing a yellowish-brown mottling of the upper surface. The mites also attack the unopened flowers, the developing flowers, and subsequently the fruits. In some instances the flowers are badly malformed and very few fruits mature.

These mites may become a nuisance to nurserymen who grow choice varieties of Lilacs, and instances of attack should be reported to East Malling.

## V. The Presence of Apple Capsid Bugs in the District of East Malling.

In view of the very serious damage caused to Apples by the various species of Apple Capsid Bugs, more especially in the districts of Cambridge and Wisbech, it is of interest to follow the movements of these insects in Kent, since they are

present in some districts, and are doubtless increasing and spreading from one plantation to another each year.

Several species of Apple Capsids have been found in the East Malling district during the last two years. At the present time, however, they cannot be regarded as common. Nevertheless growers must realise that two species of injurious capsids are increasing in numbers in many parts of the county, and should the present rate of increase continue, Capsid Bugs will be one of the worst pests in a very short time. Already a number of apple plantations, chiefly in the Swanley and Canterbury districts, are infested with Capsid Bugs to an alarming extent. One neglected orchard near East Malling was attacked by these Bugs for the first time during the summer of 1927.

The commonest species of Capsid at East Malling was *Lygus pratensis*. Fortunately this species is not the injurious Capsid Bug. It feeds upon the foliage of Apple, Currant, and a great variety of other plants.

The Pernicious Apple Capsid Bug (*Plesiocoris rugicollis*) was present in many Apple plantations. It feeds upon the foliage and the developing fruits. Considerable damage has been caused by this bug, which appears to be the commonest injurious species in the Swanley district. *Lygus pabulinus*, which is a very troublesome pest in the Cambridge and Wisbech areas, is also found at East Malling, but did not do much serious damage here in 1926 and 1927.*

VI. Slugs Destroying Hops in the Spring.

Several reports have been received from growers, during the spring of 1926 and 1927, to the effect that slugs are very troublesome in Hop gardens. The slugs attack the new Hop shoots just as they begin to grow. In many instances the tips of the shoots are nibbled away, causing the bines to go "blind." The slugs usually work at night, but may be found on the hills during the day, especially on wet days.

The slugs have been controlled in some Hop gardens by lime. To obtain the best results the lime should be sprinkled around the hills at night, when the slugs are actually feeding upon the hops. This method does not appear to be entirely satisfactory, because the lime has little or no effect upon the slugs after it has been on the gound for some two or three days. Some seasons it is necessary to make two or three applications, in order to keep down the slug attack, before the hops grow sufficiently to be out of reach of the slugs.

Naphthalene, as commercially supplied, has been used for slug control. The results are conflicting.

In one instance it appears that the slugs were killed when they came in contact with naphthalene, and the Hops in question were not attacked again that year.

* During 1928, however, this bug caused considerable havoc amongst red and black currants and gooseberries at East Malling. Full details of this will appear in a later report.

Naphthalene was used in the same hop garden the following year, but it did not seem to have any appreciable effect upon the slugs.

## VII. The Fruit Tree Red Spider.

The Fruit Tree Red Spider (*Oligonychus ulmi* C. L. Koch) is very common in most fruit plantations. Apples, Plums and, to a lesser extent, Pears are the usual host plants of this mite.

The mite winters in the egg stage. The small red globular eggs are deposited on the branches and around the buds and spurs. The eggs are seen to best advantage on sunny days.

This mite commences to hatch out from the egg stage during the second week of April. The hatching period extends over several weeks. During 1927 the hatching from the winter eggs lasted about three weeks. The mites feed upon the foliage within a few hours of hatching. The first moult takes place after three to seven days. In the first stage the mite possesses three pairs of legs. The adult mites begin to lay eggs on the under surfaces of the leaves in May.

When this mite is present in small numbers it causes very little damage to the trees, and cannot be considered a pest of importance. In some orchards, however, it has become exceedingly common, especially where tar-oil washes have been applied for several years in succession. The damage caused is two-fold. First, the leaves change from a fresh green to a dull silvery colour. A badly infested tree can readily be detected by the peculiar colour of the leaves. Second, the developing fruits and the young growth are partially checked. This pest occurs in greater numbers, and does most harm to Apples, in the latter part of June and in July, at the period when the trees should be making their maximum growth.

*Control Measures.*

Lime-Sulphur applied as a pre-blossom spray, at the rate of 1 in 30, controls the Red Spider to a large extent. A second application is also necessary, since all the spiders have not hatched by the time the first spray is put on the trees.

This post-blossom Lime-Sulphur spray should be put on at the rate of 1 in 80. Considerable success has been obtained by two applications of Liver of Sulphur. The first spray should be applied as late as possible, just before the blossoms open. The second spray should go on directly the blossoms have fallen.

*Formula :* Liver of Sulphur 50 ozs., Soap 5 lbs., Water 100 gallons. An additional spreader may be added if necessary.

The success of Red Spider control depends upon time of application of the spray. The first spray must be used as soon as the winter eggs have hatched. The second spray must also be used before the spiders begin to lay their summer eggs on the leaves.

## VIII. The Raspberry Mite.

The Raspberry Mite (*Eriophyes gracilis* Nal.) has been very troublesome on a number of young seedling Raspberries grown at East Malling. The mites attack the buds, the result being numerous branched and dwarfed canes. Attempts to control this mite with Lime-Sulphur have been carried out. Lime-Sulphur applied at the rate of 1 in 20 killed a large percentage of the mites. Subsequent observations showed that numerous mites were still present on the canes. It would appear that two or possibly three applications of Lime-Sulphur will be necessary to eradicate the mite entirely.

Experiments in this direction are proceeding.

# Section V.

## Hops.

# MANURIAL TRIALS WITH HOPS.

By J. AMOS and T. N. HOBLYN.

Six years' crop records have now been obtained from the Field Manurial Trials with Hops, begun at East Malling in 1922 (1) to test various organic manures as possible substitutes for dung in supplementing sulphate of ammonia, and (2) to compare the comparative values of different forms of phosphatic manures. From the trials designed later to test various quantities and forms of potash, five and four years' records respectively are available. The variety used for the whole series of trials was the commercial variety Tutsham, grown on the butcher system at a distance of 7 ft. by 6 ft., giving a plant of 1,037 hills to the acre.

Although it was realised that some of the treatments in the organic and phosphate series might probably give inconclusive results, it seemed reasonable to expect that after a period of time, some at least would give some significant results.

Unfortunately, however, the issue has been clouded by the ravages of "mosaic" disease, which has in many of the tests, so reduced the number of hills as to render comparison between the various treatments difficult if not impossible. Furthermore, it has been found that where the number of hills has been reduced, owing to wider spacing, the yield per hill has been invariably increased and any possible manurial effect consequently obscured.

It is, however, proposed to give here the complete records of each plot to date, together with an analysis of the figures in which the relationship between yield and number of hills is dealt with.

The full scheme of the various manurial treatments was given in detail in the 1924 Report, and this is again included here in order to give a complete picture of the trials.

The actual manurial treatments, in the first two series were those suggested by Mr. A. H. Burgess, B.Sc., of the South-Eastern Agricultural College, Wye. The underlying idea in the first series was to test the comparative value of different forms of organic matter as compared with dung, and not (primarily) of different quantities of manure.

The organic matter has been given in different forms, such as dung, shoddy, feathers, castor meal and hop bines, which have been applied in standard quantity, but each has been analysed annually and the *total* nitrogen supplied to each plot has been made up to 350 lbs. per acre by dressings of sulphate of ammonia.

It is realised that this practice involved the addition of widely different quantities of sulphate of ammonia to different plots as is indicated on the table of manurial treatment below, and this fact must not be lost sight of in interpreting the results.

Similarly in the phosphate series and one of the potash series, the form of the fertiliser has been varied whilst keeping the total quantity of phosphorus and potash respectively constant.

In order not to cloud the issue, the other constituents, phosphates and potash, have been similarly equalised on these plots by dressings of superphosphate (up to a total of 400 lbs. phosphate ($Ca_3$ $(PO_4)_2$) per acre), and muriate of potash (up to a total of 200 lbs. potash ($K_2O$) per acre).

The following table is given as an example and shows the actual dressings, based on the analyses of all the manures, applied to each Plot ($\frac{1}{1\frac{1}{2}}$ acre) in the organic series in 1927.

*Series* 1. *Substitutes for Dung.*

| | Lbs. N. | $Ca_3(PO_4)_2$ | $K_2O$ |
|---|---|---|---|
| *Plots* 1 *and* 12.—" Dung 18 tons per acre | | | |
| 1½ tons Dung containing | 16.8 | 23.5 | 16.8 |
| 58.8 lbs. Sulphate of Ammonia containing | 12.4 | — | — |
| 28.3 lbs. Superphosphate containing | — | 9.8 | — |
| | 29.2 | 33.3 | 16.8 |
| *Plots* 2 *and* 11. " Shoddy 36 cwt. per acre." | | | |
| 3 cwt. shoddy containing | 24.3 | — | — |
| 23.2 lbs. Sulphate of Ammonia containing | 4.9 | — | — |
| 31.4 lbs. Muriate of Potash containing | — | — | 16.8 |
| 96.2 lbs. Superphosphate containing | — | 33.3 | — |
| | 29.2 | 33.3 | 16.8 |
| *Plots* 3 *and* 10. " Castor Meal 36 cwt." | | | |
| 3 cwt. Castor Meal containing | 15.8 | — | — |
| 63.6 lbs. Sulphate of Ammonia containing | 13.4 | — | — |
| 31.4 lbs. Muriate of Potash containing | — | — | 16.8 |
| 96.2 lbs. Superphosphate containing | — | 33.3 | — |
| | 29.2 | 33.3 | 16.8 |
| *Plots* 4 *and* 9. Alternate Dung and Shoddy. Dressings similar to Plots 2 and 11 in 1927. | | | |
| *Plots* 5 *and* 8. " Feathers 18 cwt. per acre." | | | |
| 1½ cwt. Feathers containing | 19.0 | — | — |
| 48.4 lbs. Sulphate of Ammonia containing | 10.2 | — | — |
| 31.4 lbs. Muriate of Potash containing | — | — | 16.8 |
| 96.2 lbs. Superphosphate containing | — | 33.3 | — |
| | 29.2 | 33.3 | 16.8 |
| *Plots* 6 *and* 7. Hop Bines 10 cwt. per acre. | | | |
| 80 lbs. Hop Bines containing | 0.8 | 0.4 | 0.4 |
| 134.7 lbs. Sulphate of Ammonia containing | 28.4 | — | — |
| 30.6 lbs. Muriate of Potash containing | — | — | 16.4 |
| 95.1 lbs. Superphosphate containing | — | 32.9 | — |
| | 29.2 | 33.3 | 16.8 |

The dung used has varied somewhat, since the experiment began. Whilst in the first two years pig and stable manure was used, recently no pig manure has been applied, a mixture of stable and London dung being used.

The actual quantity of Hop bines grown on the plots receiving their organic manure in this form, has been cut up and ploughed in each year. The weights given in the table are approximate dry weights.

Series 2, which was designed to test the value of different forms of phosphatic manures, was conducted on the same principles. Each plot has received a general dressing of shoddy (2-3 tons per acre), sulphate of ammonia (1-2 cwt. per acre), and a general dressing of muriate of potash (4 cwt. per acre). The phosphates are supplied in different forms. The actual amount of each phosphatic manure varied slightly from year to year, on the basis of their analysis, in order to ensure each plot receiving an equivalent amount of phosphate—400 lbs. $Ca_3(PO_4)_2$. If any of the phosphatic manures, on analysis, was found to contain nitrogen, this was balanced on the other plots by equivalent increases in the shoddy dressing.

The different treatments included in Series 2 and the approximate annual dressings were as follows :

*Series 2. Different Phosphatic Manures.*

Plots 1 and 12. Superphosphate, approx. 10 cwt. per acre.
Plots 2 and 11. Dissolved Bone Compound, approx. 12 cwt. per acre.
Plots 3 and 10. Steamed Bone Flour, approx. $5\frac{1}{2}$ cwt. per acre.
Plots 4 and 9. Phosphatic Guano, approx. 7 cwt. per acre.
Plots 5 and 8. Basic Slag, approx. 8 cwt. per acre.
Plots 6 and 7. No Phosphate.

The acre devoted to trials with potash manures was divided into two series.

Series 3a. is designed to test the effect of giving different *quantities* of potash. Muriate of potash was the form used, and the plots were planned as follows :—

*Series 3a. Different Quantities of Potash.*

Plots 1 and 4. No Potash.
Plots 2 and 5. 2 cwt. per acre Muriate of Potash.
Plots 3 and 6. 6 cwt. per acre Muriate of Potash.

Series 3b was laid out for the purpose of testing the relative value of different *forms* of potash. The plots were as follows :

*Series 3b. Different Forms of Potash.*

Plots 7 and 10. Muriate of Potash (3 cwt. per acre).
Plots 8 and 11. Sulphate of Potash (approx. 3 cwt. per acre).
Plots 9 and 12. Sylvinite (approx. 7 cwt. per acre).

The actual amounts of the two latter dressings were adjusted from year to year, according to analysis, in order to ensure the application of amounts of $K_2O$ equivalent to those in the fixed dressing of muriate of potash.

All the plots in both potash series have received equal dressings annually of shoddy (2 tons per acre), sulphate of ammonia (1-2 cwt. per acre), superphosphate (6 cwt. per acre) and steamed bone flour (3 cwt. per acre.)

*Application of the Manures.*

All the organic, phosphatic and potassic manures have been applied in late winter, usually during January, and these have been ploughed in immediately, This method was adopted to prevent some of the manures from being carried by wind from plot to plot, and to make the cultivation of the plots comparable. The sulphate of ammonia has been applied in two or three dressings in the spring and summer months. During the period, two applications of lime have been given to all plots as a general dressing.

It should be mentioned that each plot is surrounded on all sides by a single guard row of hills.

Table I. gives number of hills (a), yield of dried hops per plot (*b*), and yield per hill (*c*) for all the plots in the trial of organic manures for the six years, 1922 to 1927.

In the last column is shown the total yield per plot for the whole period, and with it is compared the average yield of a hill and the average number of hills in each year.

It will be noticed at once that where two plots are treated alike, the one with the higher yield is that which has had fewer hills destroyed by disease ; this might be expected. If, however, the mean yields per hill are examined it will be found that nearly always where a number of hills are missing from a plot, the yield per hill is materially increased owing to the consequent wider spacing of the hills.

For example, in 1927, Plot 10 produced altogether 49 lbs. of dried hops less than Plot 3, but the forty hills which remained in the plot in this year produced 3.00 lbs. per hill, whereas the sixty-five hills on Plot 3 produced only 2.60 lbs. per hill. This difference of 0.4 lbs. per hill, would make a difference of nearly 4 cwt. per acre, and its importance is obvious.

It will thus be readily agreed that this factor has cut right across the experiment and that great care must be taken before it is assumed that any difference in yield is due to the manurial treatments.

It must be observed here that occasionally it will be found that badly affected plots still maintain a low rate per hill. This is probably due to the difference in distribution of the disease, since it will be readily seen that, for example, a patch of hills missing in one corner of a plot only, will not affect the spacing of the remainder.

TABLE I.

*Annual Yields of Plots devoted to Trials of Organic Manures, 1922 to 1927.*

| Treatment | 1922 | | | 1923 | | | 1924 | | | 1925 | | | 1926 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | a No. Hills p. Plot | b Yield p. Plot lbs. | c Yield p. Hill. lbs. | a | b | c | a | b | c | a | b | c | a | b | c |
| 1 Dung .. .. | 61 | **91** | 1.36 | 68 | **124** | 1.82 | 65 | **266** | 4.09 | 66 | **191** | 2.89 | 67 | **191** | 2.85 |
| 12 Do. .. .. | 61 | **94** | 1.54 | 58 | **79** | 1.36 | 53 | **208** | 3.92 | 52 | **165** | 3.17 | 53 | **152** | 2.87 |
| 2 Shoddy .. .. | 65 | **63** | 0.97 | 66 | **109** | 1.65 | 66 | **251** | 3.80 | 66 | **189** | 2.86 | 64 | **167** | 2.61 |
| 11 Do. .. .. | 60 | **108** | 1.80 | 61 | **82** | 1.34 | 64 | **241** | 3.77 | 61 | **188** | 3.08 | 62 | **169** | 2.73 |
| 3 Castor Meal .. | 64 | **76** | 1.19 | 66 | **109** | 1.65 | 67 | **259** | 3.87 | 66 | **195** | 2.95 | 66 | **185** | 2.80 |
| 10 Do. .. .. | 64 | **108** | 1.69 | 64 | **104** | 1.62 | 62 | **225** | 3.63 | 61 | **195** | 3.20 | 56 | **169** | 3.02 |
| 4 Dung and Shoddy alternately .. | 68 | **85Sh** | 1.25 | 66 | **107D** | 1.62 | 66 | **253** | 3.83 | 65 | **199** | 3.06 | 65 | **188** | 2.89 |
| 9 Do. .. .. | 68 | **107** | 1.57 | 67 | **110** | 1.64 | 59 | **229** | 3.88 | 58 | **193** | 3.33 | 59 | **170** | 2.88 |
| 5 Feathers .. | 68 | **74** | 1.09 | 68 | **84** | 1.24 | 66 | **248** | 3.76 | 64 | **212** | 3.31 | 65 | **173** | 2.66 |
| 8 Do. .. .. | 67 | **95** | 1.42 | 66 | **114** | 1.73 | 59 | **235** | 3.98 | 59 | **190** | 3.22 | 55 | **164** | 2.98 |
| 6 Hop Bines .. | 67 | **71** | 1.06 | 67 | **87** | 1.30 | 64 | **242** | 3.78 | 61 | **201** | 3.30 | 59 | **166** | 2.81 |
| 7 Do. .. .. | 65 | **120** | 1.85 | 65 | **119** | 1.83 | 60 | **228** | 3.80 | 57 | **176** | 3.09 | 53 | **159** | 3.00 |

Sh.—Shoddy applied in this year for the first time.

D.—Dung applied in this year for th

TABLE II.

*Annual Yields of Plots devoted to Phosphate Trials, 1922 to 1927.*

| | 1923 | | | 1924 | | | 1925 | | | 1926 | | | 1927 | | | Total Yields. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| c eld Hill. bs. | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | Mean No. of Hills. | Mean p. Hill p. year | Total p. Plot. | |
| .99 | 65 | **94** | 1.45 | 66 | **233** | 3.53 | 65 | **174** | 2.68 | 64 | **158** | 2.47 | 63 | **141** | 2.24 | 64.8 | 2.23 | 865 | 1849 |
| .56 | 67 | **114** | 1.70 | 67 | **251** | 3.75 | 66 | **192** | 2.91 | 66 | **173** | 2.62 | 60 | **148** | 2.47 | 65.7 | 2.50 | 984 | |
| .19 | 67 | **105** | 1.57 | 68 | **226** | 3.32 | 67 | **183** | 2.73 | 65 | **160** | 2.46 | 60 | **138** | 2.30 | 65.7 | 2.26 | 892 | 1866 |
| .52 | 66 | **119** | 1.80 | 68 | **253** | 3.72 | 65 | **183** | 2.82 | 66 | **178** | 2.69 | 63 | **141** | 2.24 | 65.7 | 2.47 | 974 | |
| .41 | 68 | **120** | 1.76 | 65 | **231** | 3.55 | 65 | **187** | 2.88 | 64 | **176** | 2.75 | 54 | **124** | 2.30 | 64.0 | 2.44 | 934 | 1830 |
| .14 | 65 | **104** | 1.60 | 67 | **262** | 3.91 | 64 | **149** | 2.33 | 65 | **175** | 2.69 | 56 | **131** | 2.34 | 63.8 | 2.34 | 896 | |
| .34 | 68 | **106** | 1.56 | 63 | **248** | 3.94 | 64 | **174** | 2.72 | 59 | **156** | 2.64 | 42 | **107** | 2.55 | 60.7 | 2.46 | 882 | 1832 |
| .19 | 67 | **112** | 1.67 | 65 | **266** | 4.09 | 65 | **187** | 2.88 | 63 | **168** | 2.67 | 55 | **136** | 2.47 | 63.8 | 2.50 | 950 | |
| .43 | 66 | **119** | 1.80 | 68 | **239** | 3.51 | 67 | **189** | 2.82 | 68 | **164** | 2.41 | 64 | **141** | 2.20 | 66.8 | 2.36 | 949 | 1864 |
| .26 | 65 | **108** | 1.66 | 64 | **244** | 3.81 | 65 | **161** | 2.48 | 63 | **176** | 2.79 | 60 | **140** | 2.33 | 64.2 | 2.39 | 915 | |
| .28 | 66 | **106** | 1.61 | 67 | **231** | 3.45 | 67 | **198** | 2.96 | 67 | **165** | 2.46 | 63 | **138** | 2.19 | 66.3 | 2.33 | 925 | 1846 |
| .15 | 68 | **106** | 1.56 | 66 | **246** | 3.73 | 64 | **197** | 3.08 | 63 | **177** | 2.81 | 50 | **117** | 2.34 | 63.2 | 2.45 | 921 | |

Fortunately, approximately half the area devoted to the trial has not been affected to nearly the same extent as the rest, and it is possible to select plots, differently treated, which have maintained on the whole nearly equal numbers of hills throughout.

Thus, considering Plots 1 to 5 only, the dung plot has the highest yield per hill and consequently per plot, while the shoddy plot has the lowest yield per plot, and in spite of a slightly smaller number of hills, a considerably lower yield per hill.

If Plots 7 to 11 are considered, the shoddy plot is again at the bottom of the list, and, while the dung plot cannot in this case be included, that receiving dung and shoddy in alternate years, which came second above, now takes the lead.

It is worthy of notice that the "shoddy" plots which gave the lowest yields in both of the duplicate series, were those which received by far the smallest applications of sulphate of ammonia.

It is not possible to test the significance of these results, and great caution must be used in drawing conclusions therefrom.

Two points however deserve attention. Firstly, it seems that the best method of spacing the hills has yet to be determined, and that it is most important only to compare hops differently treated when the hills under each treatment are spaced in a like manner.

Secondly, it seems unlikely that the object of this experiment, i.e., to find a suitable substitute for dung, has been attained under our conditions, since there are certainly some grounds for believing that the applications of dung have been more beneficial than the rest.

Table II. is similar to Table I. and deals with the trials of phosphatic manures. It will be seen that the actual plot yields vary little, while the hill yields also exhibit considerably less variation than those on the organic manure trial. This is probably due in part to fewer outbreaks of mosaic disease.

There seems little likelihood that any significant difference exists between the manurial treatments in this trial. However, until these trials have been repeated under far more advantageous conditions, it would be unsafe to draw the too obvious conclusions that under East Malling conditions the withholding of phosphates altogether has had no detrimental effect, and that no form of phosphate has made any difference.

It is perhaps worth noting that the whole of this series received shoddy as its organic base, and the whole series take their places, as regards yield per hill, with the shoddy plots in Series 1, as being the least prolific. Against this must be placed the fact that there are far fewer gaps due to disease in Series 2.

However, the two possible indications of the ineffectiveness of shoddy and phosphate under our particular conditions are suggestive, since they have some confirmation in two separate, if rudimentary, manurial trials with black currants.

Table III. shows the results for the trials of potassic manures. As has been noted before, in the first half of these trials, the quantity of potash alone is varied.

Comparing plots of approximately the same number of hills, it appears that, while the application of potash has probably increased the yields, the increase is of exceedingly doubtful significance where a treble quantity was applied.

In the second half of the trial, the kind of potassic manure is varied. In this case, there is apparently little, if any, difference between sulphate of potash and sylvinite.

Both plots on which muriate of potash was applied were badly attacked by mosaic and it is not possible therefore to compare their yield with that from the other plots.

A close study of the yields from year to year suggests that possibly the application of " single " potash has a cumulative beneficial effect, whilst the application of treble potash may perhaps have had a detrimental effect towards the end of the period.

## General Observations.

Each year prior to picking, a general survey has been made of the plots, but it has not been possible to pick out any outstanding feature within a given series, except in the case of the potash trials. In this series it has been noticed that the large leaves on the no potash plots lose their green colour earlier, becoming purplish yellow and falling before those on the plots receiving potash.

In comparing the organic with the phosphatic series the former have almost invariably produced heavier bine, retained their green colour longer, and have been somewhat later in ripening.

The organic series have also produced on the whole slightly heavier crops per acre than the phosphatic series in spite of the fact that they were worse affected by mosaic.

In picking, one set of plots in a series has been picked in some years a week before its duplicate set, and where this has happened, the later picked plots have shown an increase in yield of two to three cwt. per acre.

This point is clearly shown in Tables I. and II. under the year 1924, where it will be seen that in both series one set of plots show a higher yield than their duplicates, which as a fact, were picked a week later.

Thus, whilst it is hardly permissible to compare the duplicate plots of one treatment, the first set of plots under different treatments may be compared among themselves and likewise the second sets, since each set was picked, as nearly as possible, at the same time.

All the potash manures used throughout these experiments have been kindly supplied by the United Potash Company Limited.

TABLE III.

*Annual Yields of Plots devoted to Potash Trials, 1923 to 1927.*

| | 1923 | | | 1924 | | | 1925 | | | 1926 | | | 1927 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | a No. of Hills. | b Yield p. Plot. | c Yield p. Hill. | a | b | c | a | b | c | a | b | c | a | b |
| 1. No Potash .. | 63 | **82** | 1.30 | 55 | **175** | 3.18 | 49 | **127** | 2.59 | 45 | **113** | 2.51 | 28 | **67** |
| 4. do. .. .. | 63 | **63** | 1.00 | 63 | **201** | 3.19 | 60 | **125** | 2.08 | 60 | **141** | 2.35 | 56 | **121** |
| 2. Single Potash*.. | 63 | **82** | 1.30 | 60 | **185** | 3.08 | 55 | **103** | 1.87 | 57 | **161** | 2.82 | 47 | **120** |
| 5. do. .. .. | 63 | **70** | 1.11 | 59 | **207** | 3.51 | 59 | **128** | 2.17 | 58 | **154** | 2.66 | 55 | **128** |
| 3. Treble Potash*.. | 63 | **69** | 1.10 | 60 | **191** | 3.18 | 61 | **148** | 2.43 | 61 | **154** | 2.52 | 59 | **136** |
| 6. do. .. .. | 63 | **81** | 1.29 | 62 | **209** | 3.37 | 60 | **145** | 2.42 | 60 | **153** | 2.55 | 58 | **125** |
| 7. Muriate .. | | | | 52 | **147** | 2.83 | 50 | **133** | 2.66 | 49 | **136** | 2.78 | 40 | **113** |
| 10. do. .. .. | | | | 59 | **162** | 2.75 | 57 | **149** | 2.61 | 50 | **151** | 3.02 | 46 | **125** |
| 8. Sulphate .. | | | | 60 | **159** | 2.65 | 59 | **143** | 2.42 | 59 | **153** | 2.59 | 54 | **128** |
| 11. do. .. .. | | | | 59 | **159** | 2.69 | 59 | **145** | 2.46 | 60 | **162** | 2.70 | 57 | **139** |
| 9. Sylvinite .. | | | | 61 | **165** | 2.70 | 58 | **154** | 2.66 | 58 | **150** | 2.59 | 47 | **119** |
| 12. do. .. .. | | | | 62 | **175** | 2.82 | 62 | **148** | 2.39 | 62 | **143** | 2.31 | 55 | **123** |

* In these plots, Muriate of Potash was used throughout.

We are also indebted to Mr. A. H. Burgess, B.Sc., who has given advice on all chemical matters and has been responsible for the computation of the quantities of manures applied annually. We also wish to thank Mr. F. W. F. Arnaud, F.I.C., Kent County Analyst, who has kindly analysed all the manures used throughout the whole range of trials. The amount of work entailed in these analyses can be realised when it is said that some fifteen manures were dealt with annually.

Both green and dry weights have been kept from all plots and several members of the Station Staff have assisted to obtain these records. In particular the drying has been carried out annually by Mr. C. Bates, while Mr. F. C. Beard recorded both green and dry weights in 1927.

## Summary.

A manurial trial of Hops was laid down in 1921 at East Malling, and the results of this trial extending over the last six years are here presented.

The experiment included :

(1) a trial of various organic manures against dressings of dung of a similar manurial value according to the analysis.

(2) the comparison of different phosphatic manures.

(3) trials of quantity and kind of potash.

The most striking feature of this experiment has been the difference in hill yields where the ravages of "mosaic" have resulted in a wider spacing of the hills. This has affected the trial to such an extent as to make the significance of any results exceedingly problematical.

In the organic series it is very doubtful whether any of the manures used were as beneficial as dung. The shoddy plots were generally the lowest in yield.

There is no evidence to show that there has been any benefit from the applications of phosphate on this soil, but the lower yield of these plots, which received their nitrogen in the form of shoddy, seems to bear out the comparatively ineffective nature of this grade of shoddy.

Applications of potash appear to have had a beneficial effect, but where a treble quantity was applied there was no increase in yield, and it seems possible that towards the end of the period the extra amount may have been even detrimental.

There seems to have been no difference between the yields of plots receiving potash in the form of sulphate and sylvinite.